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COMPUTER AND COMPUTING TECHNOLOGIES IN AGRICULTURE II, VOLUME 1

IFIP – The International Federation for Information Processing

IFIP was founded in 1960 under the auspices of UNESCO, following the First World Computer Congress held in Paris the previous year. An umbrella organization for societies working in information processing, IFIP's aim is two-fold: to support information processing within its member countries and to encourage technology transfer to developing nations. As its mission statement clearly states,

IFIP's mission is to be the leading, truly international, apolitical organization which encourages and assists in the development, exploitation and application of information technology for the benefit of all people.

IFIP is a non-profitmaking organization, run almost solely by 2500 volunteers. It operates through a number of technical committees, which organize events and publications. IFIP's events range from an international congress to local seminars, but the most important are:

- The IFIP World Computer Congress, held every second year;
- Open conferences;
- Working conferences.

The flagship event is the IFIP World Computer Congress, at which both invited and contributed papers are presented. Contributed papers are rigorously refereed and the rejection rate is high.

As with the Congress, participation in the open conferences is open to all and papers may be invited or submitted. Again, submitted papers are stringently refereed.

The working conferences are structured differently. They are usually run by a working group and attendance is small and by invitation only. Their purpose is to create an atmosphere conducive to innovation and development. Refereeing is less rigorous and papers are subjected to extensive group discussion.

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COMPUTER AND COMPUTING TECHNOLOGIES IN AGRICULTURE II, VOLUME 1

*The Second IFIP International Conference on Computer
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Edited by

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Foreword

The papers in this volume comprise the refereed proceedings of the Second IFIP International Conference on Computer and Computing Technologies in Agriculture (CCTA2008), in Beijing, China, 2008.

The conference on the Second IFIP International Conference on Computer and Computing Technologies in Agriculture (CCTA 2008) is cooperatively sponsored and organized by the China Agricultural University (CAU), the National Engineering Research Center for Information Technology in Agriculture (NERCITA), the Chinese Society of Agricultural Engineering (CSAE), International Federation for Information Processing (IFIP), Beijing Society for Information Technology in Agriculture, China and Beijing Research Center for Agro-products Test and Farmland Inspection, China. The related departments of China's central government bodies like: Ministry of Science and Technology, Ministry of Industry and Information Technology, Ministry of Education and the Beijing Municipal Natural Science Foundation, Beijing Academy of Agricultural and Forestry Sciences, etc. have greatly contributed and supported to this event. The conference is as good platform to bring together scientists and researchers, agronomists and information engineers, extension servers and entrepreneurs from a range of disciplines concerned with impact of Information technology for sustainable agriculture and rural development. The representatives of all the supporting organizations, a group of invited speakers, experts and researchers from more than 15 countries, such as: the Netherlands, Spain, Portugal, Mexico, Germany, Greece, Australia, Estonia, Japan, Korea, India, Iran, Nigeria, Brazil, China, etc. are gathering Beijing to review the new advancement of Information and Communication Technology (ICT) applications for sustainable agriculture and food quality and safety control, to present new research findings, and to look for the new challenges and opportunities in the future.

Information technology, the convergence of computing and communication technologies, has had an enormous impact on all aspects of socio-economic development and human life in the past 30 years. Powered by the unprecedented and continuous advances in microelectronics and photonics, the power and capacity of our expanding information infrastructure has risen exponentially, while simultaneously its cost has fallen also exponentially. At least for the foreseeable future, the exponential pace of technology improvement is likely to be continued. The modern ICT is playing increasingly important roles in every facet of agricultural and biological system improvement. While traditional sectors of agricultural

technology are being constantly updated, the new sectors, such as biological informatics, information network services, information & knowledge-based precision farming system are bringing new concepts and contents into the agricultural & food chain management. The arrival of new requirements for agricultural system sustainability is accompanied by greater challenge in our profession. The goals for farming productivity, resources conservation & environmental sustainability require to develop intelligent equipment, technologies & services in extension of ICT for agriculture. The automated data acquisition is the fit way to provide spatial and temporal high-resolutions and safe documentations. The huge amount of raw data needs to be processed by a easy-to-use and safe data processing systems. A well-founded documentation will be the base of many agricultural applications in the future. A web based data management and information system are able to provide safety and effective information management for the farmers-avoiding problems with local installed software, time and costs. To promote ICT for agriculture, we need “Simplicity Theory”, that is to find the simplest method to solving real problems in farming management. To develop a low-cost with high technologies are the future of innovation activities of ICT engineers for agriculture.

The main subjects of this conference are:

- Exploitation of the strategic problems on ICT for agricultural resources, environment & production system management, web-based technology & agro-information and knowledge service system;

- Spatial information technologies (GPS, GIS, RS) for agriculture, modeling of resources, ecological and biological systems; Precision Agriculture; advanced sensors and instrumentation for farm use; & process automation; expert system and knowledge system & DSS development;

- Applied software development for farm users and macro management;

- Intelligent & virtual technology for agriculture, knowledge dissemination and remote education, etc.

More than 432 academic manuscripts have been received by this organizing committee. After review process by a group of experts, 244 English papers are accepted and published by Spring IFIP US. Taking this opportunity, We would like to express our gratefulness to the hard word by all the contributors and members of Academic Committee.

Finally, we would like to extend the most earnest gratitude to our organizers, College of Information and Electrical Engineering (CAU), EU-China Centre for Information & Communication Technologies (CAU), also to Beijing Eu-Chi Technology Co., Ltd., all members and colleagues of

our preparatory committee, for their generous efforts, hard work and precious time!

This is the Second series of conferences dedicated to real-world applications of computer and computing technologies in agriculture around the world. The wide range and importance of these applications are clearly indicated by the papers in this volume. Both are likely to increase still further as time goes by and we intend to reflect these developments in our future conferences.

Daoliang LI

A handwritten signature in black ink, reading "Daoliang LI" in a cursive style.

Chunjiang Zhao

A handwritten signature in black ink, reading "Chunjiang Zhao" in a cursive style.

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SOME POSSIBILITIES OF STUDYING THE PRECISION FARMING IN ESTONIA, METHODS AND RESULTS OF COMPLEX INVESTIGATION

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Abstract: It is a fact that crops growth conditions vary greatly in the same field. Provisionally actual growth conditions are made up of many components, i.e. variation of natural conditions (climate & soil), results of effect of machinery on soil (soil compaction) and unfavourable conditions for plant growing. In Estonia rather widely used ATV are causing remarkable damage to landscapes. All collected data were georeferenced by means of a GPS-receiver and postprocessed for position correction. For ATV damages assessment the trajectory was recorded. On damaged sites both area and form of damage were assessed. The collected data were compared to the digital soil map.

Economic loss on the average, due to unfavourable conditions for plants growth in the case of winter rye "Portal" was 131 euros per ha, for Melilotus 18.5 euros per ha and for spring barley "Anni" 1000 euros per ha.

Key words: GPS, soil, yield, ATV, penetrometer, rye, melilotus

1. INTRODUCTION

Previous studies have proved the efficiency of the GPS-based precision farming as regarding the quality of the final product and protection of environment and its applicability in intensive agricultural production. A number of positive examples can be given such as: Backes, M. and Plümer, L. (2003), Kim, Y. and Reid, J.F. (2003), Shibusawa, S. (2003). As far as Estonia is concerned, search of possibilities of application of precision

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farming has been under way since 1999. By now, GPS-receivers accuracy for both position and area measurements has been studied. Six receivers are compared and results declared, that although position accuracy for GPS receivers is not remarkably good, area measurement errors are acceptably low even on non-corrected GPS-receivers, compared to traditional measurement methods. Therefore, a GPS-receiver is suitable for area measurement through its robustness, ease of use and fast results.

We have relevant positioning experience as a result of use of a satellite navigator, still, through the years, our main problem has been the diversity of soils. So a question arises: how large a soilscape unit will be for to plausibly determine such a diversity and appreciate the factors influencing the final yield of crops. It appeared that even in the USA with its very large fields the authors Q.E. Larson and P.C. Robert point out as an example of Minnesota (Larson and Robert, 1991) that when soil maps are overlaid by landscape maps, the soilscape becomes extremely large. It is not feasible to manage each soilscape unit as separate field with conventional practices. The size of a soilscape unit may vary from one hectare to many hectares. As Estonian fields are many times smaller, we limited ourselves to many times smaller soilscape units. It differs in the case of a particular field. We have not left aside experimental patches where in co-operation with PhD Agr. Peeter Viil the said experimental patches were compacted with tractor MTZ-82. In this case the size of experimental patches was 12.5 m² (Nugis *et al*, 2004, 11-14). Even on such a small area it is possible to specify the variability of the physical state of soil. It is one thing when we affect the soil deliberately and artificially, the other thing is if it occurs at random. Extremely negative factors may occur in the field incidentally and specifying of these by means of a navigator is of considerable importance. At the same time another approach is possible by trying to model bioproductivity taking into account the soils climatic conditions in extreme sites. The author of this conception is Professor Heino Tooming and it is being developed by PhD. Biolog. Jüri Kadaja. To be brief, these ideas have been reflected in a number of publications. Connected with the topic of this particular work is the source: Nugis, E., Kadaja, J., Võsa, T. (2003).

Still, Estonia is halfway towards the level that has been achieved in developed countries nowadays. Despite of this, in our research work we have set wide-range objectives. Thus, the main objectives of our research workers are to investigate the possibilities of increasing the efficiency of agricultural machines and the respective technologies in Estonian soil and climatic conditions. To this end we have tried:

- to study the soil physical properties by using of tramlines system;
- to discover new methods (results of complex investigations related to GPS technologies) for improving and stabilizing the quality of the yield and preservation of environmental ability;
- to study new ways of effective trafficability.

Through this project related to the GPS technology, we have tried to find:

- some new possibilities of providing favourable soil physical properties and their adequate assessment;
- results of crop production after several damages;
- dynamics between appropriate indices of soil compaction and crop yield.

This work has been accomplished within the framework of the grant work No. 6888 of the Scientific Foundation and its duration is four years beginning from the year 2006.

2. MATERIALS AND METHODS

Soil units, study sites, co-authors/author of experiments are as follows:

Fragi-Stagnic Albeluvisol (sandy loam), *Haage* Agro Ltd., quite near Tartu, N58°22' and E26°37' (tramlines and winter rye "Portal"), co-authors of field experiments: Mr. Andres Härm, Dr. Hab. Eng. Edvin Nugis, PhD Jaan Kuht, MSc. Geogr. Kersti Vennik;

- *Enti-Umbri- Podzol* (loamy sand), landscape, recreation centre Andu Ltd. quite near Otepää, N58°04' and E26°26', special highway for ATV (All Terrain Vehicle), co-author of experiments MSc.Geogr. Kersti Vennik;

- *Endoeutri-Mollic Cambisol* (sandy loam), field with chosen random deep tracks after the application liquid organic manures Juuliku piggery, Saku Community, quite near Tallinn, N59°18' and E24°36' (after that sowing the spring barley "Julia"), co-authors of field experiments Dr. Hab. Eng. Edvin Nugis and PhD-student Taavi Võsa;

- *Calcari- Eutric- Cambisol* (sandy loam), experimental field of Agricultural Research Centre (PMK), N 58°58' and E 24°43', Kuusiku, quite near Rapla (*Melilotus*) co-author of field experiments MSc. Agr. Heli Meripõld.

- According to our scientific research programme we have organized both field and field-laboratory experiments. We set our targets:

- to achieve stable quality of yield sustainable also to the appliance for the EU Standard;
- to test new pioneer cultures decreasing this way vulnerability to soil compaction.

Most of our investigations were carried out by using GPS receiver Trimble GeoExplorer 3 for specifying the co-ordinates of soil samples and the damaged areas in the field. For GIS data management and primary analysis, computer programme Pathfinder Office 2.80 (Trimble Inc.) was

used. Further data analysis was carried out by means of Microsoft Excel 2003.

We have also used some experiments for measuring the soil physical properties in several soil layers: penetrometer MOBITECH for registration of cone resistance, Eijkelkamp's ring kits (100 cm³) for measuring soil bulk density and percometer for measuring soil volumetric moisture content through dielectric conductivity and permittivity, respectively. Crop yield was measured by ordinary weighing with a weighbridge in the case of rye and by means of tests weights in the case of melilotus.

3. RESULTS AND DISCUSSION

Crop damages

As can be seen in Fig. 1 and Table 1, there are significant damages on winter rye canopy. These areas are not producing grain although they have got their amount of fertilizers, pesticides, seeds, soil tillage and seeding work. Thus, expenses have been made but no yield harvested. This is neither economically nor ecologically desired result. Calculations show that in this field from 94 to 163 euros get lost due to winter damages. It is not clear yet whether all these damages are soil-originated because the winter of 2006 was very cold and snowless and, consequently, plants suffered a lot.

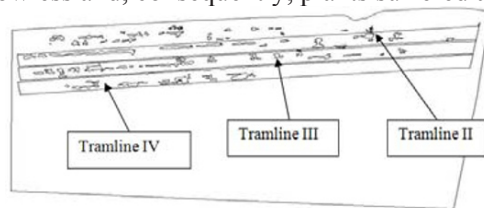


Fig. 1. An excerpt from field map with crop damage areas and tramlines in the field of "Peedimäe", Haage Agro Ltd.

Table 1. Results of the observation made by means of GPS-receiver GeoExplorer 3 of winter damages of the winter rye in the field "Peedimäe" (Haage Agro Ltd.)

Number of tramline	Area per tramline, ha	Yield t ha ⁻¹	Damages, i.e. empty crop area			Lost income €
			ha	m ²	%	
II	1.36	4.6	0.01	1216	8.9	163
III	1.32	4.6	0.01	1015	7.7	136
IV	1.37	4.7	0.007	730	5.1	98
Average	1.35	0.96	0.009	978	7.2	131

As can be seen from the Table 1, thanks to GPS receiver it became possible to determine on a large scale the damages caused due to

unfavourable winter conditions, i.e. empty crop area where nothing but weeds grew. Crop yield that was assessed in the range of each tramline separately, varied greatly because of empty areas, which, as a matter of fact, is the result of differences in growing conditions of the winter rye "Portal". The latter exerts a substantial effect on the quality of crop yield.

A similar economical loss can be calculated in the case of *melilotus*. Observed field had suffered noticeable damages, zero *melilotus* plant areas making up in total of 285 m². The measured yield from this field was 145 kg seeds per ha⁻¹ and the seed price on calculations was 4.5 euros. Consequently, damaged areas of fields reduced the income from the field by 18.5 euros per ha⁻¹.

Both cases serve as examples of heterogeneity of actual fields as compared to good farms. A much worse picture can be observed on the farms with lower agronomical culture of soil tillage and incorrect input management.

Soil Erosion and Trafficability

We applied the same principles in completely different domain, i.e. in assessing erosion-hazardous sites of soil. The ATV track (highway) under observation was passed together with a GeoExplorer in operation and the map below was obtained (Fig. 2).

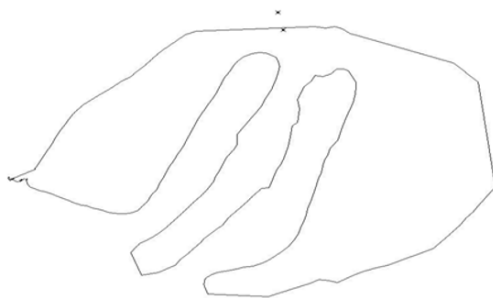


Fig. 2. Example of outline of a special highway for ATV, N58°04' and E26°26'

In this map crosses mark the soil sample co-ordinates where the above-mentioned instrumental investigations of soil physical properties were carried out and which can be seen in Fig. 3 below.

There can be observed two erosion-hazardous places which are marked by rings in Fig. 3. The signs of erosion hazard were in their initial stadium. This situation is hazardous because it may turn into an irreversible process in the case of a long period of heavy rains. At the present stage, this is to illustrate the particularity of our approach.

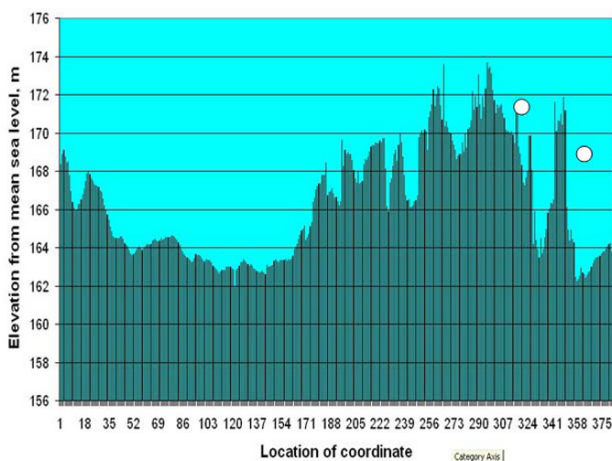


Fig. 3. Changes in the altitude from MSL on the highway for ATV

Table 2. The aftereffect of repeated compaction of soil in Juuliku experiments in 2002

Variant of experiment	Co-ordinates of the object	Covered with cultured plants, %	Penetration resistance, N cm ⁻²	Moisture content, % (w w ⁻¹)	Yield, t ha ⁻¹	Lost income ^{*)} , €
Checked, not compacted	N59°18'44.4'' E24°36'47''	90	288	20.6	2.1	734
Fresh track	N59°18'44.3'' E24°36'46.2''	10	322	18.9	0.4	1164
Old track	N59°18'44.2'' E24°36'46''	50	311	19.9	1.3	936

Note: if the yield is 5 t ha⁻¹ (many years mean)

We are to face a rather serious situation when considering the situation of a field where both consequences and protection of environment are ignored. For this purpose we had chosen a field in the phase of sprouting of spring barley "Anni". The field had suffered of extreme trafficability and winter swine sludge in large amounts was poured via a hose of a truck tank onto it. In spring a sad sight could be seen where in the field there were deep tracks with maximum depth up to 33 cm. Still, in the field untouched places could be found (calculated area 12.5 m²) and old tracks left from autumn which were also taken under observation. For the results see Table 2.

Our opinion is: no comments.

4. CONCLUSIONS

As result of the complex investigations and obtaining the relevant information it enabled the growers to produce high quality cereals in

different soil and climatic conditions of Estonia and, consequently, to get higher incomes. A data bank (accessible and stable in functioning) of quality indicators for most widespread cereals varieties and suitable digital maps will be produced. Probably by these innovative investigations it will be possible to improve the agricultural sector thanks to patentable inventions and corresponding implementation. Probably, it will be possible to cover very important to Estonia topic areas, GIS , GPS, and precision farming. In conclusion, it can also be pointed out that the methodology worked out by us where the main attention is paid to substantial deviations cropped up in the course of soil tillage and in entertainment sector. These deviations can be specified by means of modern GPS-receivers and assessed in complex. Lost income speaks for itself and gives a reason to a farmer as well as to an economist to re-estimate soil tillage strategies and to exclude risks.

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OPTIMAL PATH PLANNING PROGRAM FOR AUTONOMOUS SPEED SPRAYER IN ORCHARD USING ORDER-PICKING ALGORITHM

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Abstract: This study was conducted to develop a software program which computes optimal path for autonomous navigation in orchard, especially for speed sprayer. Possibilities of autonomous navigation in orchard were shown by other researches which have minimized distance error between planned path and performed path. But, research of planning an optimal path for speed sprayer in orchard is hardly founded. In this study, a digital map and a database for orchard which contains GPS coordinate information (coordinates of trees and boundary of orchard) and entity information (heights and widths of trees, radius of main stem of trees, disease of trees) was designed. An order-picking algorithm which has been used for management of warehouse was used to calculate optimum path based on the digital map. Database for digital map was created by using Microsoft Access and graphic interface for database was made by using Microsoft Visual C++ 6.0. It was possible to search and display information about boundary of an orchard, locations of trees, daily plan for scattering chemicals and plan optimal path on different orchard based on digital map, on each circumstance (starting speed sprayer in different location, scattering chemicals for only selected trees).

In efficiency, developed path from this program was compared to conventional path by calculating travel distance on several occasions. Optimum path for rectangular-shaped orchards traveling whole trees showed the same working path as conventional method. But, for irregular-shaped orchards, the program developed in 5% shorter path than conventional method.

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When optimum path was created to travel randomly selected trees, the program developed in 11.5% shorter path. The program always developed shorter path on any shape of orchard. Order-picking algorithm based optimal path developing program in orchard showed efficiency of traveling distance and expected to present path which lead working time and cost efficiently in orchard.

1. INTRODUCTION

Research has been progressed for unmanned autonomous driving for agricultural machine. Possibility of unmanned autonomous was confirmed from identifying basic information of field (Blackmore, 1993), identifying objects in real-time (Toda, 1993). Research of unmanned autonomous driving could be divided with agricultural chemical spraying algorithms areas such as artificial intelligent controller for backward drive on trailer attached tractor (Cho, 1995) and actual system development with variety sensors such as image processing, ultrasound sensors, terrestrials magnetism sensors and Global Positioning System (Ki, 1996).

An agricultural chemical spraying for fruit orchards is essential tasks that prevent the loss of production from 30 to 35 percent (Cho, 1996). Despite of farmer wearing protective device, pesticide poisoning incident and damages appears from pesticides penetrative on skin. Therefore, unmanned speed sprayer on orchard had to be researched and system developed. Remote control and wireless communications within a grove induced by the cable of an unmanned autonomous driving speed sprayer (Jang, 1995), application with differential global positioning system (DGPS), ultrasonic sensor and fuzzy control (Lee, 1998), e-map based DGPS fuzzy control (Lee, 1999) are those cases.

One of important element is decision making for autonomous driving path. Efficiency gets improved by using electronic maps. In case of orchards, most of driving direction for machines is keep circling between trees. So efficiency of travel distance was not contributed.

When specific points of trees have to be cared in orchard, efficiency could be necessary. In case of partial operation needed on specific trees, optimum path should be decided for unmanned autonomous speed sprayer. Therefore, development of the optimum path decision making program is necessary. On this study, solution of optimum path for orchard by using order-picking algorithm was developed (Cho, 2002). Order-picking algorithm was first started on finding goods on warehouse to optimize movement distance.

The concrete purposes of this study are as follows.

- 1) Making electronic map which has location and breeding information of trees in orchard by using DGPS.

- 2) Developing software program for shortest path on speed sprayer's using order-picking algorithms based on information of electronic map.
- 3) Evaluation of created work path on custom driving path.
- 4) Evaluation of created work path on case of specific trees has to be treated Stress-strain experiment

2. MATERIALS AND METHODS

2.1 Unmanned autonomous speed sprayer

Possibility of trailer attached tractor driving backward (Cho & Ki, 1995) has shown and it means it is much easy for speed sprayer controlled to drive backward. Autonomous speed sprayer was considered that driving backward is possible because for order-picking algorithm to be applied. This study was conducted base on hypothesis of autonomous speed sprayer with DGPS and electronic map and also can be controlled to be move backward.

2.2 The configuration of electronic map

2.2.1 The configuration of database

Database was constructed with location information such as boundary of orchard, positions of trees; breeding information such as heights, width, radius of trunk, disease appeared; pesticides treated dates, trees and which trees has to be treated. Those were developed with Microsoft Access program. Table 1 indicates the database table and field.

Table 1 Database table used for attributes

Table name	Table field
FIELD_NAME	Name of the field
	Distance between trees
	Distance between columns of trees
BOUNDARY_MAP	Coordinates of boundary points
WORK_DATE	Date of scattering
	ID of the field to be scattered
TREE	Coordinates
	Entity of trees
SPRAY	ID of trees to be scattered
DISEASE_NAME	Name of disease
	Pesticide for disease

2.2.2 Boundaries of the orchard, location of orchards and making route points map

Boundary maps are connected in the database stored the each point of BOUNDARY_MAP table and it to pull up the map in a straight line. When to use it, it can be possible that operation speed sprayer within operation boundaries the move this judgment, and also to determine where you can.

Information about the location of orchards is marked on the boundary map using the information in their fields in TREE table of database and is indicated in two circles that are the thickness of trunk and distance between trees.

The map of middle route points is indicated in mark that is set in passing point of speed sprayer considering speed sprayer of rotation and condition of the operation path.

The data in the database is mapped from using Microsoft Visual C++ 6.0 and figure 1 is three types of implementing a virtual map of the orchard. Numerical values in the figures are shown the latitude and longitude, as GPS location data

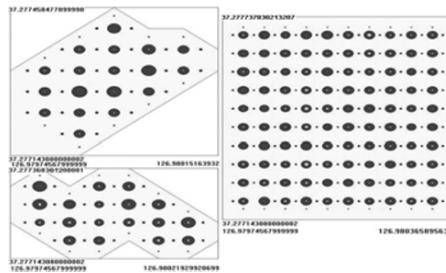


Fig. 1 Programmed boundary, tree and via-point map of 3 types of field map.
(Field type 1: left top, 2: left bottom, 3: right)

2.3 Making operation path as using electronic map

2.3.1 Assumption of agricultural chemical spraying

It assumes that the speed sprayer passes all the passage of orchards and spray twice to minimize the time of agricultural chemical spraying and equal agricultural chemical spraying operation passage(Figure 2.b). And It assumes that only with the vertical direction of the driving speed sprayer can't rotate 180-degree in the middle column of orchards considering the reality of the orchard. Because It assumes to spray twice the middle of orchards in same column sets point of agricultural chemical spraying. If orchards do not have the same column in the orchards, the half of distance

between trees on orientating vertical direction of speed sprayer sets point of agricultural chemical spraying.

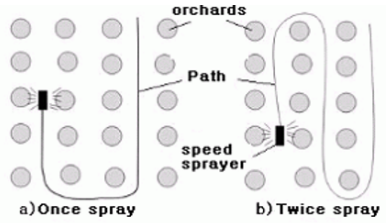


Fig. 2 Method of spraying chemicals for speed sprayer on orchard.

2.3.2 Order-picking algorithm using dynamic programming

Dynamic programming that is multi-level decision-making across the dynamic programming for the optimization is method that solve problem of cascading decision on the issue, through the decomposition or split while reducing the size of the problem. Order-picking is algorithms for efficient performing process that the machine items of orders from customers. It assumes that the position of the goods in warehouse is orchards that need agricultural chemical spraying.

The following description of the physical location of my orchards and orchards can be expressed as in Figure 3 represents the following explanation. The physical location of the orchards in orchard is the following explanation and figure 3 shows the following explanation. Moving path is from the first column of orchards on left including orchards l to first column of orchards on right including orchards r. If T_i is partial path for agricultural chemical spraying, it can be divided into two different routes.

a_i : the ending point of pathway i

b_i : the starting point of pathway i

T_i^a : the entry on the pathway i

T_i^b : the entry under the pathway i

The method of moving pathway $i-1$ to i is the following two ways.

t_a : In the case of moving on the column of orchards

t_b : In the case of moving down the column of orchards

The method of agricultural chemical spraying orchards in pathway i is the following four ways.

t_1 : In the case of moving the pathway

t_2 : In the case of no entry the pathway

t_3 : In the case of the entry under the block then exiting out again

t_4 : In the case of the entry on the block then exiting out again

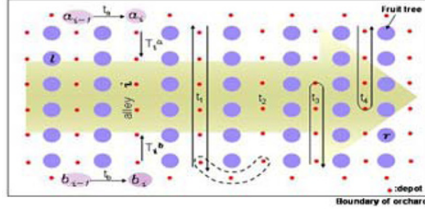


Fig. 3 Possible traveling path of speed sprayer in orchard.

A t_2 is in the case of no agricultural chemical spraying orchards in pathway. Partial path T_i is above-mentioned t_w ($w=1, 2, 3, 4, a, b$) and $T_i + t_w$. The time that speed sprayer pass path $T_i + t_w$ is $f(T_i + t_w)$.

Procedures are as follows for the creation of order-picking.

Step 1 : The dependant path that include agricultural chemical spraying orchards l (column of orchards closed with boundaries at the start of agricultural chemical spraying) is the following two ways.

T_l^a : From node a_l to node a_l and step is progressed.

T_l^a : From node a_l to node b_l and step is progressed.

T_l^b : From node b_l to node a_l and step is progressed.

T_l^b : From node b_l to node b_l and step is progressed.

Step 2 : If each of the successive path i locates between path l and r and includes agricultural chemical spraying orchards, T_i^a and T_i^b are as follows.

$$T_i^a = T_{i-1}^a + t_a + t_4 \text{ if, } f(T_{i-1}^a + t_a + t_4) < f(T_{i-1}^b + t_b + t_1)$$

$$T_i^a = T_{i-1}^b + t_b + t_1, \text{ otherwise}$$

$$T_i^b = T_{i-1}^b + t_b + t_3 \text{ if, } f(T_{i-1}^b + t_b + t_3) < f(T_{i-1}^a + t_a + t_1)$$

$$T_i^b = T_{i-1}^a + t_a + t_1, \text{ otherwise}$$

If path i doesn't include agricultural chemical spraying orchards and are as follows.

$$T_i^a = T_{i-1}^a + t_a$$

$$T_i^b = T_{i-1}^b + t_b$$

Step 3 : Final path(column of orchards closed with boundaries at the end of agricultural chemical spraying) is as follows.

$$T_r^a = T_{r-1}^a + t_a + t_4 \text{ if, } f(T_{r-1}^a + t_a + t_4) < f(T_{r-1}^b + t_b + t_1)$$

$$T_r^a = T_{r-1}^b + t_b + t_1, \text{ otherwise}$$

$$T_r^b = T_{r-1}^b + t_b + t_3 \text{ if, } f(T_{r-1}^b + t_b + t_3) < f(T_{r-1}^a + t_a + t_1)$$

$$T_r^b = T_{r-1}^a + t_a + t_1, \text{ otherwise}$$

Making final operation path is to select the shortest distance T_i^a and T_i^b at each step in each step through the process, generated from the above four kinds of path.

2.4 Making operation path using order-picking algorithm

The generated path is assumed that starting point of speed sprayer is the outline of orchard. If a number of path that speed sprayer can enter in orchard are many or The farmhouse is located in the middle of orchard so the starting point of operation is not regular, it can't be used directly in creation of path. In order that speed sprayer can pass between trees, 3 pass-points is set up around orchards in consideration of the radius of gyration of first and last orchards on column of orchards(dotted line of figure 3). When the starting point of operation is located in orchard(figure 5,7) after orchard is split into two parts, spraying is progressed on one side, then spraying is progressed and contact with former operation on other sides.

3. RESULT AND INVESTIGATION

3.1 Making operation path for all agricultural chemical spraying operations

Putting three type of orchard, eclectic map is made and changing starting point pf speed sprayer, distance of speed sprayer using operation path of customary method(It can drive only forward) and using developed algorithm are compared and analyzed. Figure 4 shows operation path using customary method and created operation path using order-picking algorithm in irregular field type 2. In each of figures, marked square point is starting point of operation and the color of between two circles is orchards that agricultural chemical spraying is needed.

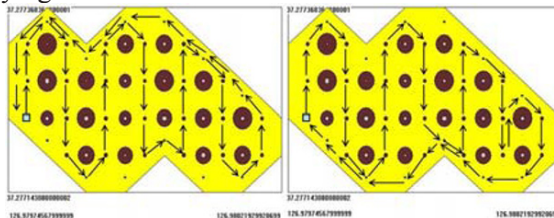


Fig. 4 Comparison of path planned by conventional (left) and order-picking(right) algorithm on field type 2.

A total distance is 163.03m by using customary method which is consider only straight direction and it is 161.0m by using order-picking algorithm. The figure 5 shows that variation of direction is related to the prevention of the breeding and extermination depends on the starting point for the matter of field type 1-irregular form. The square in the figure indicates initial position. About three types of field, a moving path of the prevention of the breeding and extermination is calculated by simulating and is described in the table 2. l_c is the operation direction length with customary method, l_o is the operation direction with developed algorithm. A $\triangle l$ is divided into a hundred parts of l_c and (l_c-l_o) . The pathway which is made by rectangular shape field type 3 is formed similar one when using a customary method and there is no difference of moving distance. On the other hand, about a irregular formed field type 1, it differ from primarily pathway and there is the differences in moving distance.

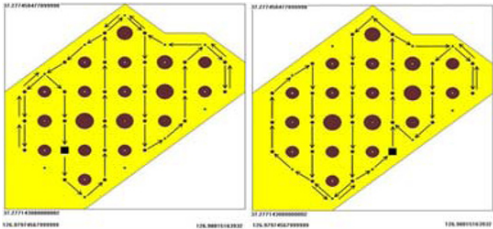


Fig. 5 Path planned by order-picking algorithm by different starting point on field type 1

Table 2 Total path length difference by applying order-picking algorithm on 3 types of field with different starting point

Field type	Coordinates of starting points		Length of the path		(%)
	Latitude	Longitude			
1	37.2772331943	126.979779511	167.5	167.5	0
	37.2771881368	126.979914829	171.0	159.2	6.9
	37.2772782505	126.980050149	169.0	164.3	3.6
	37.2773233073	126.980117808	172.0	162.9	5.3
2	37.2772331937	126.979779511	163.0	160.9	1.3
	37.2771881368	126.979914829	188.6	170.9	9.4
	37.2771881368	126.980117808	181.9	166.1	8.7
	37.2773233073	126.980185468	178.8	169.3	5.3
3	37.2771971482	126.979830254	774.3	774.3	0
	37.2771971482	126.979886637	767.25	767.25	0
	37.2771971482	126.979943024	770.78	770.78	0
	37.2771971482	126.979999404	767.25	767.25	0

3.2 Making operation path for selective agricultural chemical spraying operations

It is necessary to make the shortest operating path when worker has to select some orchards. Figure 6(a) shows that only path of normally straight driving when it is needed to do work at selected some orchards in field type 1 and the length of all paths is 135.3m. Figure 6(b) shows formed path using order-picking algorithm and the length of all formed paths is 124.0m. Figure 7 shows change of agricultural chemical spraying path with change of speed sprayer starting point about irregular field type 1.

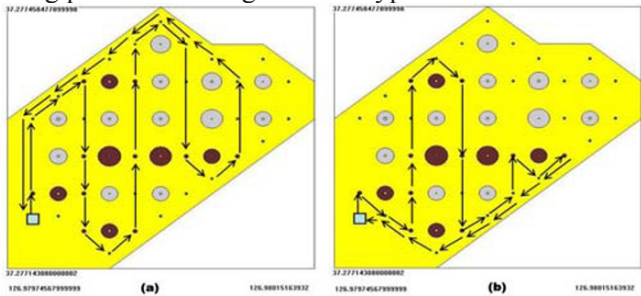


Fig. 6 Path planned for selected trees using (a) conventional algorithm and (b) order-picking algorithm.

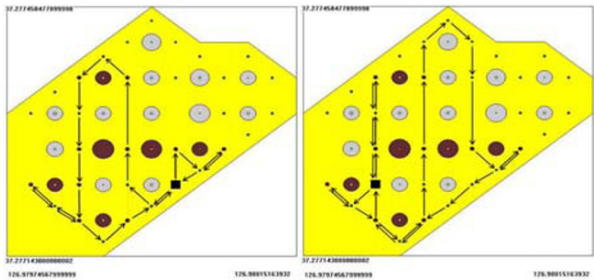


Fig. 7 Path planned for selected trees using order-picking algorithm with different starting point.

Table 3 shows change of length for agricultural chemical spraying path with applied algorithm and change of speed sprayer starting point when the path of agricultural chemical spraying is made with selected some of orchards in irregular field type 1 and rectangular field type 3. created length of pathway is shorter 9.1% than created length of pathway according to customary method.

4. SUMMARY AND CONCLUSION

In this study, order-picking algorithm using dynamic programming that is used in warehouse is applied in orchard and work path of reversible autonomous speed sprayer is used.

The definite result is followed

1. About all parts of orchard, when agricultural chemical spraying operation is progressed, in rectangular type orchard (field type 3), created path is same with operation path of customary method. But in irregular type orchard, created path shows effect of path reduction at 5.06%

2. About selected specific parts of orchard, when agricultural chemical spraying operation is progressed, in rectangular type orchard (field type 3), created path is 9.1% shorter than operation path of customary method (It can drive only forward). Finally, in this study, developed program shows that in case of operation in irregular type orchard is more effective than operation of rectangular type orchard.

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THE USE OF A METEOROLOGICAL STATION NETWORK TO PROVIDE CROP WATER REQUIREMENT INFORMATION FOR IRRIGATION MANAGEMENT

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Abstract: Despite of the water use increment for other sectors than agriculture, the water use for irrigation is the main water consumer in global scale. However, irrigation has been pressured by the civil society to improve water use efficiency in agriculture, to prevent water scarcity for human population that grows continuously, mainly in developing areas of the planet. On the other hand, the irrigation practice is considered the main tool to increase water use efficiency, either for increasing crop production or for keeping rural works in the agricultural areas. The water use efficiency can be improved through the adoption of an efficient irrigation management and programming that results in water conservation. Several methods of irrigation management have been developed and used in the last few decades, but the adoption of the majority of them by the irrigated grower was limited by the cost, time of installation, maintenance and local difficulties that the selection of a specific method involves. In arid regions, the decision of "when" and "how much" to irrigate is relatively simple. However, in wet regions when complementary irrigation is used, the irrigation scheduling is a complex task, mainly due to the water added from rainfall events. The Sistema Irriga™ is basically a service of irrigation management developed by the Federal University of Santa Maria, Brazil. The criteria used by this method to decide the amount of each irrigation application is based on crop parameters of the irrigated crop, soil physical characteristics, meteorological conditions and characteristics of the irrigation

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system and irrigation method, combined with a mathematical model to determine the reference and crop evapotranspiration. This paper describes all factors and parameters used by the Sistema Irriga™ service, since the data acquisition (plant, soil, weather and irrigation system information), data processing and how the irrigation recommendation is available to the farmers.

Keywords: Weather station, reference evapotranspiration, irrigation management.
Introduction

1. INTRODUCTION

Recent studies published by FAO (2002) showed some alterations in the world food production panorama, comparing to previous estimates. According to Food and Agricultural Organization (FAO), there is an increase in food production, besides the tendency to decrease demographic rates, resulting in a reduction of agricultural use of the natural resources. The increase in agriculture productivity is the most important reason for increasing the world production. Developed countries increased 70% their food production mainly due to the incorporation of new technologies in cropping systems and management practices, especially irrigation.

The FAO has estimate that the irrigated area will be around 300 million hectares in 2030. This statistic will add great pressure to improve irrigation water management, since the agricultural are responsible for 70% of fresh water consumption.

Many technologies can be used by farmers to combine yield increasing with environmental protection, such as conservation tillage systems, using integrate pest and disease management and the best use of biotechnology. However, the improvement of water use efficiency in agricultural crop system will only be possible with the adoption of an adequate irrigation management system, to avoid waste of water and reduction in production due to excessive or under irrigation. According to Howell (2000), without a proper irrigation management, irrigated agriculture may undermine the sustainability of the system.

The technology present in many areas is very high, including meteorology and agriculture, making possible the automatic tracking of several meteorological variables in real time. Not only meteorological data can be automatically acquired, but also other data related to agriculture are being monitored specially related to plant and soil.

One of the main applications of real time meteorological data in agriculture is to estimate the reference evapotranspiration (ET_o). It is possible to build a network with several automatic weather stations (AWS), which increase the quality of collect meteorological data. Combining these

variables with an adequate irrigation management system will improve the water use in agriculture.

In South America, specifically in Brazil, the use of AWS is recent; and a large number is installed in research institutes, however, the use of AWS by farmers has been increasing continuously. Based on meteorological data collected from a particular region, soil, plant and equipment information, it is possible to recommend when is necessary to irrigate and how much water the farmer should apply on a specific irrigated area. The irrigation recommendation is available to users by phone or through Sistema Irriga™'s web page - www.sistemairriga.com.br.

The main objective of this paper is to describe the Sistema Irriga™ criteria for irrigation management, especially the data collection, transmission and calibration of the used AWS network, as well as the ETo and Etc determination and the irrigation scheduling information distributed to the farmers through the internet.

2. SYSTEM DESCRIPTION - DEVELOPMENT

2.1 Automatic weather station location

The AWS network is used to satisfy several needs, ranging from a simple aid-to-the-observer to fully automatic stations that provide information to weather forecast, aeronautical and agricultural meteorology. When the purpose is to estimate the ETo for dissemination of irrigation crop requirements, the AWS location follows the same rules established by de World Meteorological Organization (WMO) for the conventional stations. Generally, the AWS's are fully accepted as meteorological stations when providing data with comparable accuracy as the ones collected from conventional stations. The AWS's have several advantages over conventional stations. In general, due to its characteristics of mobility, they can be installed in isolated areas, without electric energy supply, for instance.

The Agricultural Engineering Department of the Federal University of Santa Maria (UFSM), Rio Grande do Sul, Brazil, had implemented a network of AWS. Nowadays, this network has a total of 86 AWS distributes in several Brazilian States and in Uruguay (Figure 1). The data measured by AWS are collected and sent directly through internet, phone, satellite, etc. to a datacenter to be processed and stored.



Fig.1: Distribution of the automatic weather station network used by the Sistema Irriga to provide irrigation management information to farmer in Brazil and Uruguay

A mathematical model is used to process the meteorological data and estimate ETo and ETc and together with crop growth, soil characteristics and irrigation system information to determined the irrigation scheduling. Furthermore, the Sistema IrrigaTM has a service that also indicates to the farmers when N fertilization has to be applied based on crop phenology.

The AWS network is distributed on major irrigated areas in Brazil. Generally, each AWS is positioned to provide information to the largest possible area, reducing acquisition, transmission and maintenance costs. The distance between the AWSs is around 50 to 70 km, since the altitude does not varies more than 200 m. The network is constantly upgraded by adding a new AWS, aimed to collect data in remote and isolated areas and improve the quality and precision of information provided by the Sistema IrrigaTM.

2.2 Data collection and transmission

The online collection presents a lot of advantages in relation to manual collection, because it does not need a person intervention. The most common forms to make the online collection is to interfacing the equipment to a CPU using available serial or USB ports. Once connected to a CPU, measured data can be read by specific software. Collected data can be stored in a local

unit (CPU) or sent to a datacenter. Data are normally transmitted to a datacenter through an internet connection (dial up connection, ADSL, cellular, satellite links, etc.). Each transmission technology has its benefits and cost. Nowadays, the internet connection using a cellular modem represents a low cost. On the other hand, satellite connections can also be used, including very remote sites, but the main problem is the high cost for implementation and maintenance. The AWS network of the Sistema Irriga® uses different data transmission systems on each irrigated region, to avoid problems on data reception and availability.

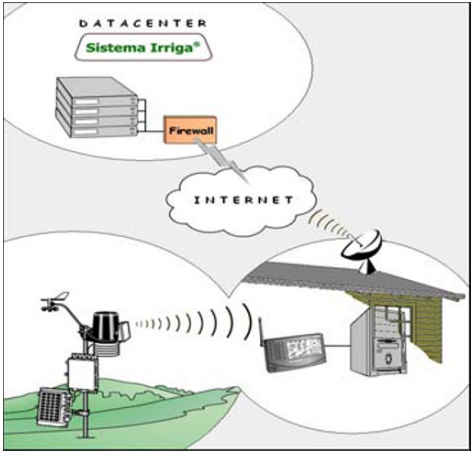


Fig. 2: Data collection and transmission from an automatic weather station to the datacenter of the Sistema Irriga™.

On table 1 is presented the data range, sensor resolution and accuracy of the meteorological data collected and processed from each AWS of the network.

Table 1: Details of the accuracy, specific measurements range of the automatic weather station network of the Sistema Irriga™.

Sensor	Range	Accuracy	Unit
Air Pressure	750 a 1060	0.3	hPa
Air temperature	-25 a +60	0.3	°C
Relative Humidity	2 a 100	3	%
Wind Speed	1.03 a 92.6	2	m/s
Wind Direction	0 a 359	5	degree
Rainfall	0 a 999.8	2%	mm
Solar radiation	0 a 1500	5	W m-2

Soon after receiving the data, the server automatically runs a filter to verify if the data are inside the specified range (Table 1). In case of inconsistency they are only stored but not used for irrigation purposes.

Currently, two SGI servers, dual-core Xeon 2 Gb of memory RAM and 2 HDs of 250Gb. Also, an off-site server DELL is used as backup. All the servers use Linux OpenSource 10.2. The data base is MySQL 5.0 supporting a 2.4 Gb database of information stored since 2002.

The servers process automatically more than 500 algorithms with information of the weather conditions, crop growth and development, soil physical characteristics, crop management system and characteristics of the irrigation system. All information is process by PHP and Javascript languages using version 5.1.6 of the PHP and Apache 2.2.

The maintenance and calibration of each sensor of AWS is a constant task. Calibration is made by specific companies of Technical Assistance. The maintenance is conducted every two years and consists of sensor reconfiguration (in the case of replacement), communication test, adjustment, cleaning, etc.

2.3 Basic parameters used by the Sistema Irriga™

2.3.1 Soil parameters

Some soil physical characteristics are fundamental for irrigation management, such as: soil water holding capacity, soil plant availability, soil infiltration, soil structure, texture, bulk density and soil porosity. In each irrigated area, soil samples are collect in trenches of approximately 80 cm length, 60 cm width and 75 cm depth. The soil profile is usually divided in three layers: superficial, intermediate and inferior. Each trench represents approximately an area of 50 hectares. Undisturbed soil samples are collected using rings of 50 mm in diameter and 25 mm height.

2.3.2 Crop parameters

Crop characteristics such as leaf area, height, root depth and distribution, plant population, canopy architecture, row space, etc. are important to determine ETc. Several field experiments have been conducted to validated crop parameters for different varieties, hybrids and cultivars. Currently, the data base of the Sistema Irriga™ has validated data of leaf area index, plant height, crop growth and development (cumulative thermal time) for the following crops: pumpkin, alfalfa, garlic, rice, cotton, potato, brachiaria, onion, carrot, barley, coffee, pea, beans, sunflower, apple, maize, sweet corn, popcorn, peach, pear, soybean, sorghum, tobacco, tomato, wheat and grapevine.

2.3.3 Irrigation system parameters

The irrigation system information, such as: minimum and maximum irrigation depth, distribution uniformity coefficient, irrigation efficiency among others, is used to determine the frequency and irrigation duration. Figures 3 presents a simplified layout of the system operation, with the basic four factors considered in each irrigation recommendation and the different ways the information reached the farmers.

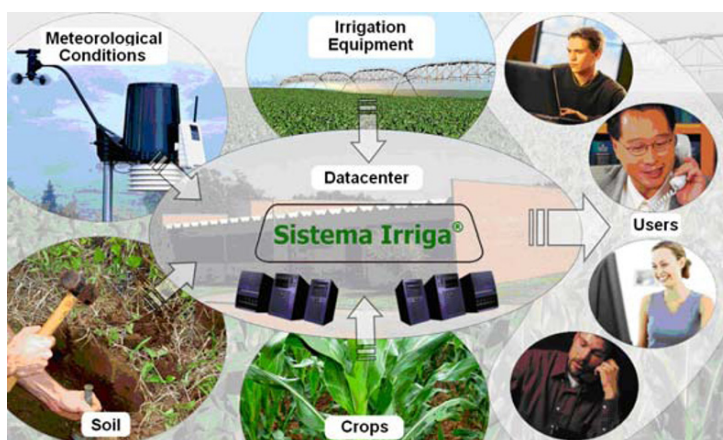


Fig. 3: Simplified layout of the Sistema Irriga™ operation.

2.4 Reference and crop evapotranspiration determination

The ETo depends basically on meteorological data. Consequently, the ETo is a climatic parameter and can be estimated based on meteorological data. The method of Penman-Monteith described in FAO-56 (Allen et al., 1998) is used to determine ETo and ETc. Initially the values of crop coefficient (Kc) used by the Sistema Irriga™ are the ones suggested for Allen et al. (1998). Constantly adjustments and/or corrections of the original Kc values are carried out in the field, generating a new set of coefficients, as a function of the different crop cultivation system, soil management, varieties, cultivars or hybrids, etc. (field experiments constantly are installed in different regions of Brazil for adjustments of the crop growth and development).

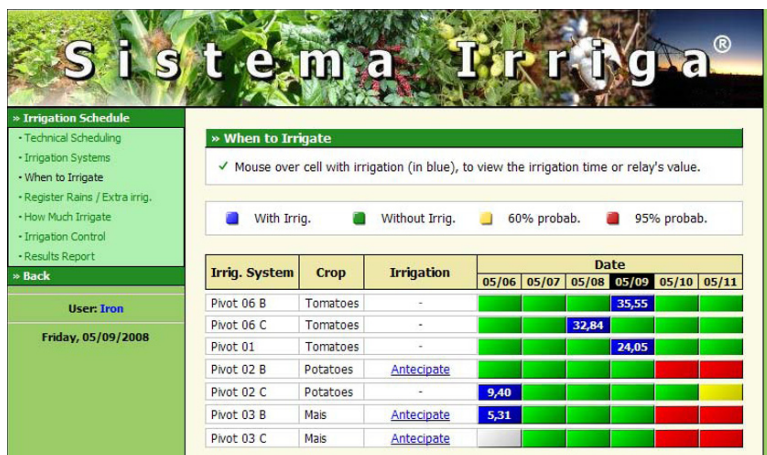


Fig.4: Main web page of Sistema Irriga™ showing daily when to irrigate and how much water to apply for each crop and irrigation system.

2.5 Irrigation scheduling

The irrigation scheduling provided by the Sistema Irriga™ easily indicates when to irrigate and how much water to apply in each irrigation. Irrigated farmers have daily to access the web page of the system (www.sistemairriga.com.br). The daily recommendation of when and how much to irrigate is based on the basic four parameters described earlier (weather, plant, soil and irrigation equipment). Besides the daily recommendation the system provide an irrigation forecast for the next 24 and 48 hours (Figure 4).

3. FINAL CONSIDERATIONS

The Sistema Irriga™ initiated as a pilot project in 1999, using only one AWS to manage 540 hectares. In 2000 and 2001, using three AWS, 2500 hectares were monitored in Southern Brazil, increasing to 10.000 ha in 2002 (using 14 AWS). The annual evolution of the monitored irrigated areas and number of farmers that uses the system is presented in fig. 5. Nowadays, more than 185,000 hectares have been monitored since the creation of the system.

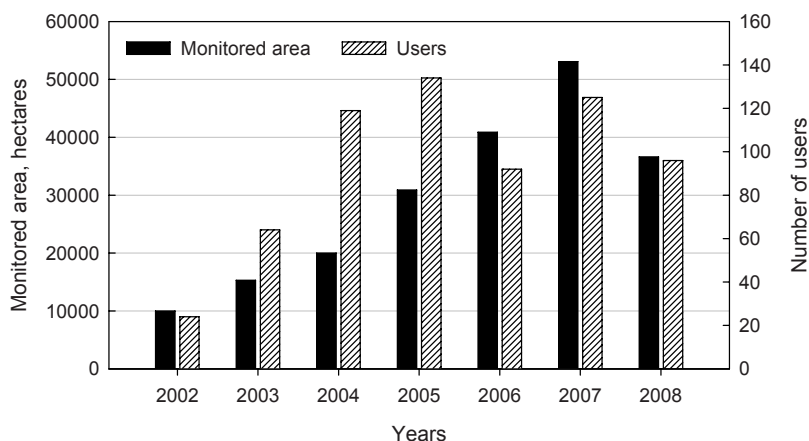


Fig.5: Annual evolution of the monitored irrigated areas and number of farmers that uses the system from 2002 to 2008.

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USE OF CERES-WHEAT MODEL FOR WHEAT YIELD FORECAST IN BEIJING

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Abstract: The CERES-Wheat model was applied to simulate yields from 2005 to 2007 at Xiaotangshan of northern Beijing. Experiment datum required by CERES-Wheat model were all collected and checked. In addition, 1974-2004 climate records were taken and calculated as predictive weather scenario used for yield forecasting. The model calibration adopted simulation results of 2005 and which of the other two years were used for validation. Model calibration was made through comparing the field-observed and model-simulated results at five stages: (i) dates of anthesis and maturity; (ii) values of LAI; (iii) biomass yields of anthesis and maturity; (iv) dry matter of leaf, stem, and grain; (v) final wheat yield. This study revealed that CERES-Wheat model can be used for the prediction of wheat growth and yield in Beijing.

Keywords: crop simulation model, wheat, yield forecast

1. INTRODUCTION

China has turned to be the largest producer of wheat in the world (FAO 2004), and nearly 95% of which is winter wheat. Considering the importance of wheat for the economy, government policy and food requirements of the state, there is a need for reliable estimates of wheat production under varied environments. On the basis of early-warning information of successive yield

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predictions during the growing season, producers and marketing boards could, for example: adjust use of fertilizers and herbicides, revise marketing plans, and decide on options for following seasons.

The official estimates of crop production in China are based on three methods at present. The first is statistical method, which works through complete enumeration for crop acreage and sample crop cutting experiments for yield. Crop sampling leads to large labor force-, material resources- and money-consuming; the second way calculates crop yield through weather model, which can get a accurate result but with a disadvantage that short of acreage information; the last method is using remote sensing (RS) to estimate grain outputs.

Crop simulation model is a process based model (de Wit, 1982), which simulates crop growth and development combine with changing climate stages and varied environmental conditions. In many cases, quantitative information on production can only be obtained through crop simulation studies and long-term climatic records (MacDonald and Hall, 1980; Bouman et al., 1995). Providing accurate estimates of the benefits and risks of alternative crop management systems with expected yield before final harvest has placed an increasing demand on crop simulation models. The use of crop simulation models for predicting crop yield has been studied extensively and there has been an increased interest in association with spatial variability and precision farming (Hoogenboom, 2000; Sadler et al., 2000; Paz et al., 2001; M. Bannayan et al., 2004). As a further extension of this approach, the predicted results can be used to determine certain management decisions.

The objective of this study was to evaluate the application of the dynamic crop process model CERES (crop estimation through resource and environment synthesis)-Wheat for forecasting final grain yield for winter wheat under growing conditions in Beijing.

2. MATERIALS AND METHODS

2.1 Experiment data

Site description

Winter wheat ('Jingdong 12') was sown during the autumn of 2004/2005, 2005/2006 and 2006/2007 at Xiaotangshan, which located in Changping of northern Beijing (N40°10'56", E116°26'29"). This area, which is representative of the irrigated fields of Beijing, is characterized by a semi-

arid climate. At this place, winter wheat is the major crop sowed by farms, and the mean air temperature yearly is 12.6°C.

Data description

The CERES-Wheat model uses daily weather data, together with a set of parameters describing crop, soil and management factors, to simulate wheat growth over the growing season (Hunt et al., 2001). To use the model in Beijing, it was necessary to obtain local values of the above parameters. Experimental information, including latitude, longitude, sowing date, descriptions of the soil series, the number of collected samples, and climate information (Table 1) are all collected from 2004 to 2007.

Table 1. Distribution of precipitation

Season	Spring			Summer			Autumn			Winter			Total
Month	3	4	5	6	7	8	9	10	11	12	1	2	
Rain(mm)	9.7	16.6	26.8	87.9	194.1	181.4	48.8	24.6	5.6	1.3	2.7	4.9	584.2
rain/season	53.1			443.4			78.8			8.9			584.2
%	9.1%			75.9%			13.5%			1.5%			100%

Standard meteorological data with the exception of solar radiation was obtained using DAVIS station from 2004 to 2007. This station provided daily values of the maximum and minimum air temperature (°C), rainfall (mm) and total wind run (m/s). Sunshine hours were gained from China Meteorological data Sharing Service System, and they were converted to daily total radiation (MJ/m²) using the method of dumin Weng (1997). Besides those, 30 years (1975-2006) of daily weather data (maximum and minimum air temperature, °C; rainfall, mm; sunshine hours, hr) were taken from China Meteorological data Sharing Service System as an input for yield forecasting. Soil inputs include drainage and runoff coefficients, first-stage evaporation and soil albedo, water-holding characteristics for each individual soil layer, and rooting preference coefficients at several depth increments. The model also requires saturated soil water content and initial soil water content for the first day of simulation. The description of the soil characteristics were shown as Figure 1 (Xuzhang Xue et al., 2003). The brown soils have characteristically light textures with water holding capacities to a depth of 1 m of 150mm or less, so the sampling of the soil deep to 1m and separated into 6 layers. The crop management data were obtained from field experiments, including plant population, planting depth, and date of planting. If the crop is irrigated, the date of application and amount is also required.

2.2 CERES-wheat model

Current major crop model systems include DSSAT (Decision Support System for Agrotechnology Transfer; USA, Canada), SUCROS (Netherland) and

APSIM (Australia) etc. CERES-Wheat model, as a process-oriented crop model provides some benefits over purely empirical models, is one of the main models that have been incorporated in DSSAT (Hoogenboom et al., 1994). The study works with CERES-Wheat Model through DSSAT 4.

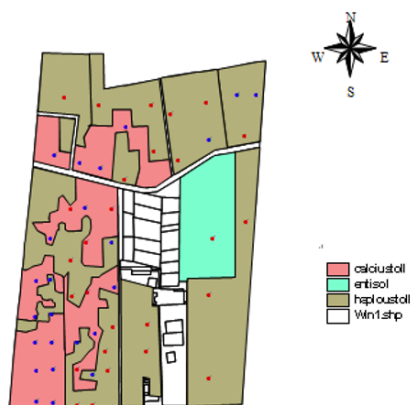


Figure 1. The soil characteristics of Xiaotangshan

CERES-Wheat is a dynamic crop simulation model that was originally developed under the auspices of the USDA-ARS Wheat Yield Project and the U.S. government multiagency AGRISTARS program (Ritchie and Otter, 1985). It forms the basis of IBSNAT, the International Benchmark Sites Network for Agrotechnology Transfer (Uehara, 1985), can be used to simulate the growth and yield of wheat under different environments. The model has been tested successfully with data from around the world. Output results could be biomass accumulation and partitioning, leaf area index (LAI), water and N balance, crop growth and yield based on daily time steps etc (Godwin and Singh, 1998; Ritchie et al., 1998).

2.3 Cultivar calibration

In order to evaluate the applicability of the CERES-Wheat model to Beijing, calibration of the model was required. The key process of model calibration was adjusting six variety-specific genetic parameters of Jingdong12. Three of these are related to developmental aspects and the others related to the growth of the crop. P1V and P1D define the sensitivity of a variety to vernalization and photoperiod. The third developmental parameter, P5, is the grain-filling duration coefficient. G1, G2 and G3 are the kernel number coefficient, kernel weight coefficient and spike number coefficient, respectively (S. S. HUNDAL, 1997). When the predicted values of the relevant growth and yield were compared with the observed values,

the six genetic coefficients were increased or decreased from the initial values. After an iterative process, those values of the coefficients which most realistically simulated the growth and yield of wheat were selected.

Model calibration was made by comparing the field-observed and model-simulated results of five stages: (i) dates of anthesis and maturity; (ii) values of LAI (leaf area index); (iii) biomass yields of anthesis and maturity; (iv) dry matter of leaf, stem, and grain; (v) final wheat yield. The CERES-Wheat model was calibrated to simulate the growth and development of winter wheat using the field-observed crop data of the 2004/2005 season experiment. The comparison of model-simulated and field-observed data was gained for validation at the period 2005/2006 and 2006/2007. In addition, 30 years (1975-2006) historical weather information was taken as statistical weather result to predict yield.

3. RESULTS AND DISCUSSION

The CERES-Wheat model simulated from realistic weather conditions, crop genotypes, soil properties and crop management practices got simulated-results. The values derived from statistic weather data (1975-2006), which used as input variables of model, were called predicted-values. This method is one of the main methods to predict weather and has been used and practiced widely. All inputs except weather data were prescribed as discussed in the previous sections. The experiment conducted during the 2004/2005 growing seasons was used to calibrate the model, and the experiment conducted during the 2005/2006 and 2006/2007 growing seasons were used for model evaluation. Forecasts of wheat yield were generated for the period 2006/2007.

Overall, the field-observed and model-simulated anthesis dates and maturity dates were in close agreement (Table 2). The difference of simulated and actual dates of anthesis is less than 6 days, which of the autumn is less than 5days.

Table 2. Comparison of observed and simulated anthesis and physiological maturity dates of winter wheat for different crop years

Crop year	Sowing date	Anthesis date (Days after sowing)		Deviation (No. of days)	Physiological maturity date (Days after sowing)		Deviation (No. of days)
		Observed	simulated		Observed	simulated	
2004/05	27/9/2004	223	225	2	262	263	1
2005/06	28/9/2005	229	233	6	265	269	4
2006/07	27/9/2006	226	232	6	263	264	5

Experiment data of 2006/2007 season was taken as an example for evaluation. Comparison of simulated-values, observed-values and predicted-

values (2006/2007) of LAI was shown as Figure2.LAI simulated by the model corresponded reasonably well with that actually observed in the field, although simulated values shows a little higher at the last 35 days. Similarly, predicted wheat LAI has also shown negative trends in the period of subsequent period. While predicted values delayed much from that of actual, especially at the period of end Anthesis and maturity. The maturity date of forecasted is 270, 6 days later than simulated date. The reason may be attributed to uncertain weather conditions in the region.

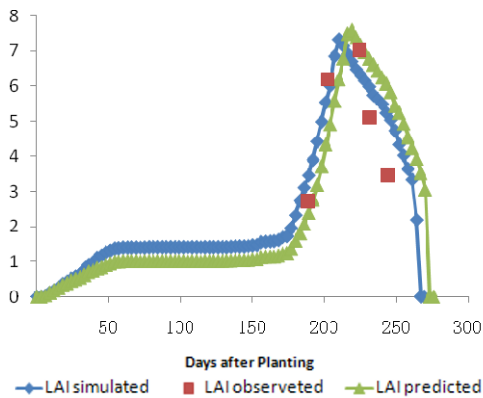


Figure 2. Comparison of simulated-values, observed-values and predicted-values of LAI for 2006

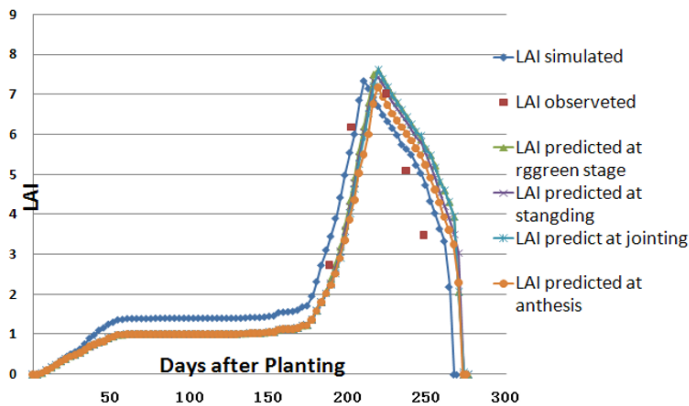


Figure3. Comparison of simulated-values,observed-values and predicted-values at main stages of LAI for 2006

Simulated wheat yield (7525kg/ha) and predicted yield (7736kg/ha) was much higher than the actual wheat yields (6992kg/ha). The deviation may be on account of dissatisfactory environment conditions, for instance water stress, N deficiency or unbalance of nutrient at subsequent period. The

statistical weather condition has a serious disadvantage that it averaged rainfall values to every day, the total water gross was the same, but it likely make a day-by-day irrigation to wheat. That is one of the reasons predicted yield much higher than simulated wheat yield.

We also worked on crop growth forecasting from main growth stage: rggreen stage, standing, jointing and anthesis. The certain growth stage as a dividing line, before that time measured weather data was used and after that time statistic weather condition used as input data. LAI at rggreen stage, standing and jointing was close to each other; while LAI result at anthesis showed obvious improve. At this experiment region, the influence of real weather data to predict result between rggreen stage and anthesis is tiny. There are 40 days between anthesis and maturity, at this period the more real meteorological data used the precision the result is. In practice, policy makers could predict wheat yield at rggreen stage got a general forecasting yield and got a more exact result at subsequent period forecasting.

4. SUMMARY AND CONCLUSIONS

As wheat is a staple crop in China, pre-harvest forecast of wheat yield is necessary to allow policy makers in the government to design policies for export/import, price fixing, storage and transportation. Crop simulation models are process based and consider almost all factors affecting the crop growth and development. With their obvious advantages, crop simulation models have become a favorite tool for yield forecasting.

The crop simulation model was run on recommended levels of inputs for the fields, but simulated and predicted yields are high. This could be due to following reasons: (a) farmers are not following the appropriate recommendation; (b) around 1–5% of the standing crop is lost during various agronomical practices such as fertilizer applications, pesticide applications, herbicide applications, tillage, irrigation etc. (A. S. NAIN, 2004); (c) 8–10% of the crop yield in fields is damaged during threshing and transportation; (d) some loss also occurs due to pests. Some assumptions made in the CERES-Wheat model may not be realistic in certain situations and these could be addressed in future investigations.

Though the approach released in the present study for wheat yield estimation and prediction showed reasonably good accuracy, it can be further improved by considering issues such as: (a) affects of plant diseases and insect pests; (b) spatial variability in soil properties; (c) spatial variability of weather; (d) interaction between rotated crops. Future research for yield forecasting can carry through by adopting the use of GIS (geographic information system) and RS (remote sensing).

The present study demonstrates the ability of the CERES-Wheat model to provide regular pre-harvest forecasting of wheat yields in Beijing. Although there is diversity, the total variety trend was corresponded reasonably well with that actually value. The model can act as a useful tool for Winter Wheat yield forecast in Beijing.

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DATA ENVELOPMENT ANALYSIS ON EFFICIENCY EVALUATION OF IRRIGATION-FERTILIZATION SCHEMES FOR WINTER WHEAT IN NORTH CHINA

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Abstract: Crop production is a process of multiple inputs (water and nutrients, etc.), and the relationships between the inputs and crop yield are very complex. This study used a model for data envelopment analysis (DEA) to evaluate the efficiency of irrigation-fertilization schemes for winter wheat in North China. The field experiments were conducted at the Xiaohe Irrigation Experiment Station in Central Shanxi Province, China. Sixteen irrigation-fertilization schemes, the combinations of four levels of irrigation (irrigation volume from 0 to 300 mm) and four levels of fertilizer (0, low, moderate and high), were considered in the experiments. Experimental results revealed that irrigation and fertilization have significant impact on wheat yield and water use efficiency (WUE). For schemes without fertilization, wheat yield and WUE tend to be the lowest for all the irrigation levels and vary little with irrigation volume. With a specified irrigation volume, wheat yield and WUE tend to increase with fertilizer level. At a specified fertilizer level, wheat yield tends to increase with irrigation volume, while WUE is less influenced by irrigation volume. Among the sixteen schemes, ten were evaluated to be DEA efficient or nearly DEA efficient. The results indicated that proper combination of irrigation and fertilization is necessary for efficient use of water and fertilizer. Low fertilizer level with no irrigation and low, moderate or high fertilizer levels with more irrigation volume are generally effective for winter wheat production.

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1. INTRODUCTION

Irrigation and fertilization are effective measures to increase crop yield, especially in arid, semi-arid and sub-humid areas (Cao, 2001). However, improper irrigation and fertilization practices may result in low water and nutrients use efficiency, groundwater depletion (Yang et al., 2006) and contamination to groundwater and water body (Zhu and Chen, 2002). Therefore, it has become a major concern in irrigation and fertilization management to increase crop yield and water use efficiency and to decrease contamination caused by nutrients loss.

The impact of irrigation and fertilization on crop yield, water use efficiency (WUE) has been extensively investigated for different crops and regions (e.g., Al-Kaisi and Yin, 2003; Li, et al., 2004; Aujla et al., 2005; Mandal et al., 2005). However, with multiple inputs (water and nutrients, etc.) for output (crop yield) and their complex relationships, it is difficult to evaluate the efficiency of irrigation-fertilization schemes using a single index, such as the crop yield, water use efficiency or nutrients use efficiency. For a multi-criteria evaluation problem, the evaluating procedure and results may also be bias due to personal preferences, attitudes and knowledge, etc. (Srdjevic et al., 2005).

Crop production function (CPF) quantitatively describes the relationships between crop yield and main influencing factors, i.e., water index shown as irrigation volume or evapotranspiration and nutrients indexes shown as fertilizer applied or nutrients uptake, etc. CPF is usually expressed as empirical functions in two types, one relating crop yield with seasonal water and nutrients indexes in the forms of quadratic, square root, Mitscherlich-Baule, linear or nonlinear von Leibig (Llewelyn and Featherstone, 1997), whereas the other with indexes partitioned over different growth stages (Sharma et al., 1992). Artificial neural networks (ANNs) have also been used in the modeling of CPF (Shang et al., 2003). However, CPFs are generally obtained through regression analysis or training of ANNs based on experiment results. The regression results represent the mean level of crop production with different irrigation and fertilization schemes, which is different from the concept of production function in microeconomics. With these CPFs, we can judge whether an irrigation-fertilization scheme is efficient or not compared with the mean level, but unable to judge which scheme is the most efficient and how to improve the inefficient ones.

To measure the efficiency of decision making units (DMUs) with multiple inputs and outputs, Charnes et al. (1978) proposed the first model of data

envelopment analysis (DEA), named CCR model. DEA uses mathematical programming techniques and models to evaluate the relative efficiency for each DMU. Evaluation results from DEA are sufficiently objective, because little personal judgment is considered. Since 1978, DEA has been applied in a wide range of fields, such as education, health care, banking, armed forces, market research, transportation and manufacturing (Zhu, 2003). In water and fertilizer management fields, DEA starts to be applied to evaluate the performance of irrigation district (Rodríguez-Díaz et al., 2004), variable-rate fertilization (Ma et al., 2004) and reservoir system (Srdjevic et al., 2005), etc.

Winter wheat is one of main food crops in North China. Although irrigation is necessary to obtain higher crop yield, water available for irrigation is limited because of the increasing water shortage in this area. Therefore, it is necessary to study proper irrigation-fertilization schemes with limited water supply. The main objectives of this study are to study the effect of irrigation and fertilizer (nitrogen and phosphorus) on wheat yield and water use efficiency, and to evaluate the efficiency of irrigation-fertilization schemes for winter wheat using DEA.

2. MATERIALS AND METHODS

2.1 Area description and experiment treatment

Field experiment was conducted at the Xiaohe Irrigation Experiment Station (112°40' E, 37°38' N and 782.6 m above sea level) during the growing season of winter wheat in 2003-2004. The Station belongs to the Xiaohe Water Resources Administration of Shanxi Province in North China. Mean annual precipitation is approximately 450mm with 70% falling in the period from June to September. Winter wheat is one of main crops in this area and grows mainly in dry seasons from October to next June. Precipitation in this period is only approximately 150 mm, which is much less than the water requirement of winter wheat of over 500 mm (Wang and Sun, 2003). Irrigation water for this irrigation area mainly comes from the Xiaohe River and groundwater. However, available water for irrigation has been decreasing in recent years due to the decrease of river runoff and groundwater depletion.

In the growing season of winter wheat in 2003/04, we carried out experiment at 24 plots to study the impact of irrigation and fertilization on winter wheat yield. Each plot was 20 m².

Four irrigation treatments (I0 to I4) with different times and volume of irrigation were considered (Table 1). At the time of sowing, diammonium

phosphate with 15% nitrogen (N) and 42% phosphorus pentoxide (P_2O_5) was applied simultaneously at the rates of 0, 375, 750 and 1125 kg hm^{-2} . With irrigation in the jointing stage, complementary fertilization of urea with 46% N was applied at the rates of 0, 112.5, 225 and 337.5 kg hm^{-2} . The combination of irrigation and fertilization treatments were given in Table 1. Among these sixteen treatments, four with moderate fertilizer rate were replicated three times.

Table 1. Irrigation and fertilization treatments for winter wheat in 2003/2004

No.	Treatments	Irrigation volume at different growing stages (mm)					Fertilization rate (kg/hm ²)	
		Winter	Jointing	Heading	Milking	Total	Seeding	Jointing
1	I0-F0-0					0	0	0
2	I0-F1-0					0	375	0
3	I0-F2-0					0	750	0
4	I0-F3-0					0	1125	0
5	I1-F0-0		45			45	0	0
6	I1-F1-1		45			45	375	112.5
7	I1-F2-2		45			45	750	225
8	I1-F3-3		45			45	1125	337.5
9	I3-F0-0	75	60		45	180	0	0
10	I3-F1-1	75	60		45	180	375	112.5
11	I3-F2-2	75	60		45	180	750	225
12	I3-F3-3	75	60		45	180	1125	337.5
13	I4-F0-0	75	75	75	75	300	0	0
14	I4-F1-1	75	75	75	75	300	375	112.5
15	I4-F2-2	75	75	75	75	300	750	225
16	I4-F3-3	75	75	75	75	300	1125	337.5

The wheat variety used for the study is Jing-9428, a common variety of wheat grown in that area. The seeds were sown on October 7, 2003 at the rate of 338 kg ha^{-2} . The row spacing was 25 cm and the sowing depth was 5 cm.

Irrigation and fertilization was applied according to the experiment design. A flow meter was used to control the amount of water applied. Irrigation for winter, jointing, heading and milking stages were applied on December 11, 2003, April 19, May 7 and May 29, 2004, respectively. Diammonium phosphate was applied at the time of sowing and urea with irrigation in the jointing stage.

Meteorological factors, including air temperature, humidity, wind speed, sunshine hours and precipitation, were monitored during the growing stage of winter wheat. Volumetric soil water content was monitored using neutron probe. Access tubes were installed at the center of each experiment plot. Soil water content was monitored at approximately 10-days' interval from sowing to harvesting for every 20 cm soil layer from the surface to 2.0 m in depth. After harvesting on June 19, 2004, wheat yield of each irrigation-fertilization treatment was measured.

2.2 Water use efficiency

Water use efficiency was calculated using the following equation.

$$\text{WUE}=0.1Y/\text{ET} \quad (1)$$

where WUE is the water use efficiency (kg m^{-3}), Y is the crop yield (kg hm^{-2}), ET is the corresponding evapotranspiration (mm), and 0.1 is a constant for units conversion. ET under soil water stress conditions was calculated using the method of single crop coefficient (Allen et al., 1998).

$$\text{ET}=K_s K_c \text{ET}_0 \quad (2)$$

where ET_0 is the reference evapotranspiration, K_c is the crop coefficient, and K_s is the coefficient describing the effect of water stress on evapotranspiration. K_s was calculated from soil water content obtained from a soil water balance model, which was modified after the model of Allen et al. (1998) by introducing an empirical equation (Wang and Sun, 2003) to describe soil water flux through the bottom of the root zone.

2.3 CCR model for data envelopment analysis

For DMUs with single input and output, the efficiency can be defined as the ratio of output to input. For DMUs with multiple inputs and outputs, Charnes et al. (1978) proposed to measure the efficiency with the maximum ratio of weighted outputs to weighted inputs subjected to the condition that the similar ratios for all DMUs are less than or equal to 1. In contrast to statistical approaches characterized by evaluations of DMUs relative to an average DMU, DEA is an extreme point method that compares each DMU to all other DMUs with weights chosen to favor the DMU being considered.

Suppose n DMUs to be evaluated. DMU j ($j=1, 2, \dots, n$) uses m inputs x_{ij} ($i=1, 2, \dots, m$) to produce s outputs y_{rj} ($r=1, 2, \dots, s$). Using DEA, the efficiency of each DMU is evaluated separately. When DMU j_0 with inputs x_{i0} ($i=1, 2, \dots, m$) and outputs y_{r0} ($r=1, 2, \dots, s$) is under evaluation, the input-orientated CCR model with non-Archimedean ε can be expressed as (Zhu, 2003; Wei, 2004)

$$\min. \quad [\theta - \varepsilon(\sum_{i=1}^m S_i^- + \sum_{r=1}^s S_r^+)] \quad (3)$$

$$\text{subject to } \sum_{j=1}^n X_{ij} \lambda_j + S_i^- = \theta X_{i0}, i=1, 2, \dots, m$$

$$\sum_{j=1}^n Y_{rj} \lambda_j - S_r^+ = Y_{r0}, r=1, 2, \dots, s \quad (4)$$

$$\lambda_j \geq 0, j=1, 2, \dots, n$$

$$S_i^- \geq 0, i=1, 2, \dots, m$$

$$S_r^+ \geq 0, r=1, 2, \dots, s$$

where θ represents the relative efficiency, λ_j is the weight of DMU j , S_i^- and S_r^+ are input and output slacks, respectively.

Suppose the optimal solution of the CCR model is $(\theta^*, \lambda_j^*, S_i^{-*}, S_r^{+*})^T$. If

$\theta^*=1$, then the DMU under evaluation is DEA efficient when $S_i^- = 0$ and $S_r^{++} = 0$, or weakly DEA efficient otherwise. If $\theta^* < 1$, then the DMU under evaluation is inefficient. For an inefficient DMU, other DMUs with non-zero optimal λ_j^* can be used to define a hypothetical efficient DMU, which shows how inputs can be decreased to make the DMU under evaluation efficient (Zhu, 2003).

To evaluate the efficiency of irrigation-fertilization schemes, each irrigation-fertilization scheme was regarded as a DMU. Three inputs were considered, including total evapotranspiration (ET), total nitrogen applied (N) and phosphorus pentoxide applied (P). Only one output, wheat yield, was considered.

3. RESULTS AND DISCUSSION

3.1 Effects of irrigation and fertilizer level on wheat yield

Both irrigation and fertilizer level have significant influence on the wheat yield, and wheat yield tends to increase with irrigation volume and fertilizer applied (Fig. 1).

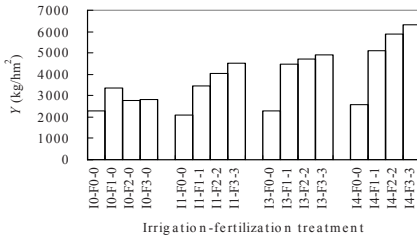


Fig. 1: Wheat yield (Y) for different irrigation-fertilization treatments.

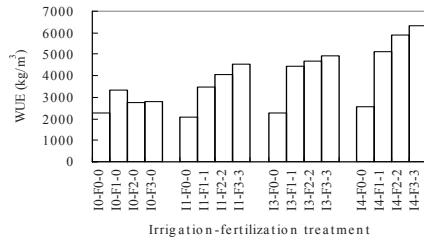


Fig. 2: WUE for different irrigation-fertilization treatments.

Wheat yield response to irrigation varies with fertilizer level. Without fertilizer application in the whole growing period, wheat yield is the lowest for all irrigation schemes and its variation with irrigation volume is small. This might be caused by severe soil nutrients stress to crop growth. It increases almost linearly with irrigation volume for non-zero fertilizer levels (Fig. 1 and Table 2). Results of linear regression between wheat yield and irrigation volume show that 1 mm irrigation volume can result in the yield increment of approximately 6.1, 9.2 and 9.9 kg hm⁻² for low, moderate and high fertilizer levels, respectively.

On the other hand, wheat yield response to fertilizer level varies with irrigation volume. Wheat yield of low fertilizer level was significantly higher

than that of the zero fertilizer level, and the increment ratios were 46%, 65%, 50%, 96% and 99% for irrigation schemes I0, I1, I3 and I4, respectively. However, with more fertilizer applied (moderate and high fertilizer levels), the increment of wheat yield became less. Especially for I0, wheat yield of moderate and high fertilizer levels were even lower than the yield of low fertilizer level. This indicates that appropriate nutrients rate for maximum yield with severe water stress is low and too much fertilizer application may result in the decrease of wheat yield. The relationship between wheat yield and fertilizer rate can be described by CPFs with a peak value, such as the quadratic or square root CPFs (Llewelyn and Featherstone, 1997).

Table 2. Irrigation and fertilization treatments for winter wheat in 2003/2004

Treatments	Evapotranspiration (mm)	Wheat yield (kg hm ⁻²)	Water use efficiency (kg m ⁻³)
I0-F2-0	291 A	2759 A	0.95 A
I1-F2-2	327 B	4035 B	1.23 B
I3-F2-2	380 C	4705 C	1.24 B
I4-F2-2	466 D	5901 D	1.27 B

Note: Data are the mean values of three replications. Values of the same column followed by different letters are significantly different at both $P=0.05$ and $P=0.01$ based on LSD test.

3.2 Effects of irrigation and fertilizer level on evapotranspiration and water use efficiency

Total water requirement of winter wheat, or evapotranspiration without water stress, was approximately 552 mm. Evapotranspiration was nearly the same for the same irrigation volume with different fertilizer level (Table 3). It averaged to be 289mm, 327mm, 380mm and 466mm for different irrigation treatments, showing a linear increasing trend of evapotranspiration with irrigation volume. The regression analysis of evapotranspiration (ET) and irrigation volume (I) yielded the following results:

$$ET=0.56 I+292, R^2=0.981, \text{ degree of freedom } n-2=22.$$

The regression result indicates that 1 mm irrigation volume can result in the ET increment of approximately 0.56 mm. In other words, the amount of initial soil water used for evapotranspiration declines with irrigation volume.

WUE was less influenced by irrigation compared with wheat yield (Fig. 2). Due to low yield of irrigation treatments I0, WUE of I0 was lower than the others. Both wheat yield and evapotranspiration increased with irrigation volume, so WUE of I1, I3 and I4 change little at a specified fertilizer level. For moderate fertilizer level, least significant difference (LSD) test shows that WUE of I1, I3 and I4 are not significantly different (Table 2). However, WUE of this group, approximately 1.25 kg m⁻³, are significantly higher than WUE of I0, 0.95 kg m⁻³.

WUE response to fertilizer level was similar to the wheat yield. WUE also increased significantly from zero fertilizer level to low fertilizer level, especially for large irrigation volume. WUE of I3 and I4 at low fertilizer

level nearly double the values at zero fertilizer level. With more fertilizer applied (moderate and high fertilizer levels), the increment of WUE also becomes less. For irrigation treatment I0, WUE also has a peak value at low fertilizer level due to the peak of wheat yield.

Table 3. Inputs, output and results of DEA for different irrigation-fertilization schemes

No.	Treatments	Input			Output Y (kg/hm ²)	Relative Efficiency θ^*	Input Slacks			Output Slack S_Y^*
		ET (mm)	N (kg/hm ²)	P (kg/hm ²)			S_{ET}^*	S_N^*	S_P^*	
1	I0-F0-0	288	0	0	2288	1	0	0	0	0
2	I0-F1-0	288	56	158	3345	1	0	0	0	0
3	I0-F2-0	291	113	315	2759	0.77	0	0	99	0
4	I0-F3-0	286	169	473	2802	0.75	0	0	169	0
5	I1-F0-0	327	0	0	2089	0.80	0	0	0	0
6	I1-F1-1	329	108	158	3453	0.88	0	0	0	0
7	I1-F2-2	327	216	315	4035	0.92	0	0.2	0	0
8	I1-F3-3	326	324	473	4520	1	0	0	0	0
9	I3-F0-0	379	0	0	2276	0.76	0	0	0	0
10	I3-F1-1	380	108	158	4465	1	0	0	0	0
11	I3-F2-2	380	216	315	4705	0.95	0	0.1	0	0
12	I3-F3-3	379	324	473	4920	0.95	0	0	0	0
13	I4-F0-0	465	0	0	2556	0.69	0	0	0	0
14	I4-F1-1	466	108	158	5095	0.99	0	0	0	0
15	I4-F2-2	466	216	315	5901	1	0	0	0	0
16	I4-F3-3	467	324	473	6310	1	0	0	0	0

Notes: ET-evapotranspiration, N -total nitrogen applied, P -phosphorus pentoxide applied, Y -wheat yield.

3.3 Relative efficiency of irrigation-fertilization schemes

The relative efficiency of irrigation-fertilization schemes were evaluated using the CCR model for DEA. Among sixteen irrigation-fertilization schemes considered, six were evaluated to be DEA efficient, including I0-F0-0, I0-F1-0, I1-F3-F3, I3-F1-F1, I4-F2-2 and I4-F3-3 (Table 3). Another three schemes, I4-F1-1, I3-F2-2 and I3-F3-3, were all close to DEA efficient. Each of these efficient or nearly efficient schemes had higher wheat yield and/or higher WUE in a certain group of schemes.

Among schemes without irrigation (I0), schemes with zero and low fertilizer level (I0-F0-0 and I0-F1-0) were both DEA efficient. With minimum water and fertilizer inputs, the scheme I0-F0-0 ranked second in wheat yield and first in WUE among all schemes without fertilization. However, this scheme is unsustainable because soil fertility may be deteriorated. The scheme I0-F1-0 ranked first in both wheat yield and WUE among I0. Schemes I0-F2-0 and I0-F3-0 were both inefficient with excess phosphorus pentoxide. Therefore, low fertilizer level is recommended for rain-fed winter wheat in the study area.

Among schemes with only once irrigation in the jointing stage (I1), the scheme with high fertilizer level (I1-F3-3) was DEA efficient, which ranked first in wheat yield among I1 and first in WUE among all sixteen schemes. Therefore, this scheme was recommended if less irrigation water is available.

Among schemes with three times of irrigation (I3), the scheme with low fertilizer level (I3-F1-1) was DEA efficient with wheat yield and WUE 5% to 10% lower than that of moderate and high fertilizer levels (I3-F2-2 and I3-F3-3), but the fertilizer applied was only 1/2 and 1/3 of the moderate and high fertilizer levels. I3-F2-2 and I3-F3-3 were both close to DEA efficient.

Among schemes with four times of irrigation (I4), the schemes with moderate and high fertilizer levels (I4-F2-2 and I4-F3-3) were both DEA efficient, with the former ranked second and the latter ranked first in both wheat yield and WUE. The scheme with low fertilizer level (I4-F1-1) was also very close to DEA efficient.

4. CONCLUSION

Experiment results of winter wheat with different irrigation-fertilization schemes revealed that irrigation and fertilization have significant impact on wheat yield and WUE. Wheat yield and WUE without fertilization are lower for all irrigation levels and change little with irrigation volume, and they tend to increase with fertilizer level at a specified irrigation volume. Wheat yield also tends to increase with irrigation volume at a specified fertilizer level. However, WUE is less influenced by irrigation volume.

DEA provide an objective approach to evaluate the efficiency of irrigation-fertilization schemes. Main advantages of the DEA are that DEA is applicable to evaluate schemes with multiple inputs and outputs using mathematical programming models and the evaluation results are objective. Irrigation-fertilization schemes for winter wheat in Xiaohe Irrigation Area in North China were evaluated using DEA. The results indicate that proper combination of irrigation and fertilization is necessary for efficient use of water and nutrients. Combinations of low fertilizer level with no irrigation, or the low, moderate and high fertilizer levels with more irrigation volume are generally effective for winter wheat production.

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LAND-USE CHANGE DYNAMICS AND CLUSTER ANALYSIS OF AGRICULTURAL STRUCTURE IN THE ZULI RIVER BASIN IN RECENT 20 YEARS

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Abstract: Based on the combined use of satellite remote sensing and geographical information systems(GIS), as well as field investigation, the land-use change dynamics and the interaction between these changes are analyzed in the Zuli River Basin located in semi-arid Loess Plateau China during the period of 1987-2005, which with typical farming-pastoral region feature of northern China. The land-use change of Zuli River Basin is divided into three successive phases. The results indicate that the area of grassland reduces 2.88%, 2.83% converting to farmland and 0.05% to urban and residential land from 1987-1993. Grassland reduces 0.25%, 0.19% converting to farmland and 0.06% to urban and residential land from 1993-2000. Farmland reduces 2.96%, 2.94% converting to farmland and 0.02% to urban and residential land from 2000-2005, respectively. Moreover, the land use changes are also analyzed respectively in the cluster analysis. According to 10 natural and social indexes of 64 towns in Zuli River Basin, it is divided into three clusters and the land-use changes of these clusters are analyzed. We proposed different stratagems in three clusters of Zuli River Basin in this paper. These significant land use changes influenced by the policy of converting cropland to forestland and the increase of population occurring within the whole basin over the study period. The key factors of future development of Zuli River basin are the adjustment of structures between farmland and grassland, and the improvement of water-using efficiency.

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1. INTRODUCTION

For centuries, humans have been altering the earth's surface to produce food through agricultural activities. In the last few decades, conversion of grassland, grassland and forest into cropland and pasture has risen dramatically in the tropics (Houghton, 1994). This acceleration has concerned about the role of land use change in driving losses in many research fields.

3S technologies such as geographic information system (GIS), remote sensing (RS) and global positioning system (GPS), have given agricultural management unprecedented capacity to quantify farmland-grassland patterns and understand spatial heterogeneity of agriculture structure (Turner and Carpenter, 1998; Griffith et al., 2000). Many studies used spatial indices landscape patterns in agricultural systems and contrast them with natural systems (Gustafson, 1992; He et al., 2000). Understanding agricultural processes at a regional scale requires quantification of the spatial and temporal variations in farmland-grassland pattern, such as the area and structure of farmland-grassland. The dynamic of spatial and temporal patterns of agricultural landscape are critically important for crop management but difficult to measure or predict with current methods.

The Chinese Loess plateau is unique landscape in arid and semi-arid regions of the world. It has been described as one of the most serious soil erosion areas in the world with an estimated annual soil loss from cropland. There is a high risk of land degradation from improper management systems, overstocking, or opportunistic cultivation, limiting of the sustainable agriculture. It is a most important farming area in China, for there is plenty of arable land. It is important for sustainable agriculture development and ecosystem restoration to develop seeded grassland into crop-forage system (Li, 1999; Li et al., 2003).

Zuli river basin is located in Loess Plateau, Northwest China, which is in northern farming-pastoral transitional zone. In recent years, because of the development of Zuli river basin, population increases, urbanization process and The Conversion of Cropland to Forest and Grassland Project, the land use changes of Zuli river basin are the interaction results between human and nature. Based on the 3s technology and survey data in the fields, we make detail analysis of the spatial and temporal changes of land use in Zuli river basin, which is the scientific support to the sustainable development of land and water resources in Zuli river basin.

2. STUDY AREA, DATA AND METHODS

2.1 Study Area

The Zuli river basin draining to the upper catchments of the Yellow river, is located between longitude 104°12'-105°33'E and 35°18'-36°34'N in the northwest China, where it is well known as an important western part of the Chinese Loess Plateau. The area of the watershed is 10,653km². The elevations range from 1,400-2,000m. The mean annual air temperature is 8.8°C at the lowest (northern) end of the basin and decreases to 3.6°C at the highest (southern) end of the basin, and the mean annual precipitation is more than 500mm at the southern end of the basin and gradually decreases northward to only 250mm in the northern end (Zhao et al., 2003). More than 60% of the annual precipitation in Zuli river basin occurred in June to September, and 50% of the annual precipitation occurred in the rainstorm form. The land use types mainly included farmland, grassland, urban and residential land.

2.2 Data

2.2.1 Land use/cover Data Set

The 1987, 1993, 2000 datasets were from Land-sat5 (TM) images during the summer season in 1987, 1993, 2000, and the year 2005 dataset was obtained from the CBERS also in the summer of this year. All datasets are treated by accurate atmospheric-geometric correction. Both these two datasets were manually interpreted based on field investigation, DEM scaled at 1:50,000 and topographic maps scaled at 1:100,000 studying area. By giving a new attribute (patch type) to each polygon the land use map, combining polygon with the same patch type. The original 18 land use types were reclassified into 6 major land use/cover types: farmland, forest, grassland, urban and residential land, bottom land, desert land. The above procedures and statistic of all the vector data and grid data in this paper were performed using ArcGIS 9.0, ArcView GIS Version 3.2 (ESRI, USA) software and their Spatial Analysis module.

2.2.2 Other Statistic Data

Crop area, population and other statistics came from Bureau of Statistics of Dingxi and Huining Country. These bureaus are authorized units engaged

in the professional surveying of local environment and statistics of social and economic development, so this data is reliable.

Tab 1. The 6 major land use/cover types and their meaning in Zuli river basin

Patch ID	Land use types	Patch type meaning
2	Forest	Arbor, shrubbery, sparse woods and tree nursery
3	Grassland	Grassland which coverage is more than 5% and land mixed rangeland with the coverage of shrub canopies less than 10%
4	Bottomland	Land covered by natural water bodies or land with facilities for irrigation and water reservation
5	Urban and residential land	Including city, industry, traffic land and mine, and rural settlement
6	Desert land	Desert, bare land, rock and gravel land
12	Farmland	All agricultural land, which including both paddy and non-irrigated uplands

2.3 Methods

2.3.1 Extract the boundary of Zuli river basin

We using hydrological module in ArcGIS 9.0 to extract the boundary of Zuli river basin. The Zuli river basin extent does not exceed the administrative boundary; Take the grassland, forest and other land patches as the outer patches; Ensure the integrity of the outer patch (Li et al., 2006).

2.3.2 The cluster analysis of social-economic data

Cluster analysis is a scientific method for studying that things of one kind come together. Similar data can be grouped into the same cluster, and then each cluster needs only one rule to describe its characteristic, which is used to differ and classify the things according to their comparability. It is a process in which there is no one to guide them. So it is a non-supervising classifying and a tool to analyze data under no hypothesis (Neslihan, 2008).

The indices of sixty four towns in Zuli river basin are as followed: population quantity, per capita grain, farmland areas per person, total grain yield, reclamation ratio, population density, average slope, average precipitation, irrigation areas, irrigated farmland ratio. All of these ten natural and social indices have different dimension and order of magnitude. After excluding the affects of different dimension and order of magnitude, we make standardizing treatment for original data by the means of standard deviation. Sixty four towns in Zuli river basin are divided into three clusters of distinct characteristics.

3. RESULTS AND ANALYSIS

3.1 The landuse change in Zuli river basin

As Figures 1 showed, the spatial and temporal land use changes in Zuli river basin is interpreted by TM and CBERS in the same method. Based on the particular investigation and the GPS data in Zuli river basin in 2005, we made the precision assessment of land use types in Zuli river basin, to present the whole precision of the land use monitoring process. As a result, the precisions of land use classification in 2000 and 2005 are 85.36% and 86.26%. The precisions are settled for the next analysis and research.

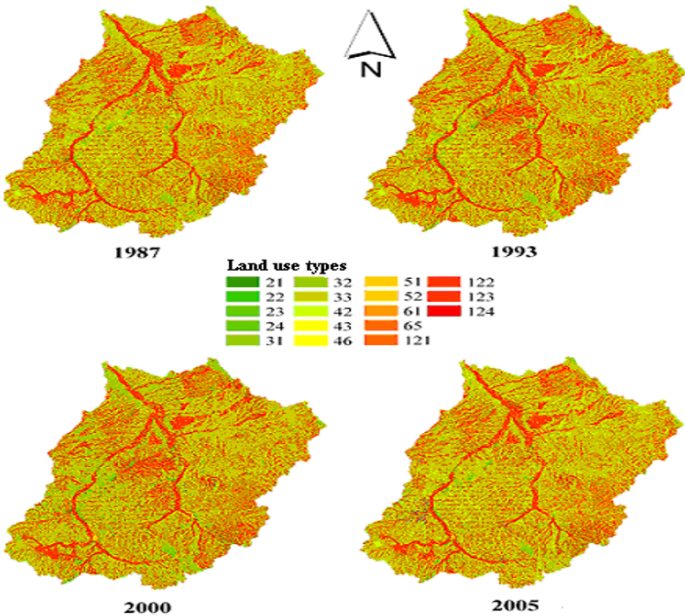


Fig1.Land use changes of Zuli River Basin from 1987 to 2005

21-forest land; 22-shrubbery; 23-open forest land; 24-other forest land; 31-high coverage grassland; 32-moderate coverage grasslands; 33-low coverage grasslands; 42-lake; 43- reservoir; 46-beach land; 51-urban land; 52- rural residential area; 61-sandy land; 65-bare ground; 121-mountainous farmland; 122-hilly farmland; 123- plain farmland; 124->25°slope farmland

As Figures 1 and Table 2 showed, farmland and grassland are the main land use/cover types in Zuli river basin in 1987, 1993, 2000, 2005. Use the Spatial Analysis module in ArcView 3.2 to calculate the cross-tabulation table, which was output as a transition matrix. The area of grassland in Zuli river basin decreased 2.88% from 1987 to 1993,

respectively 2.82% of grassland converted to farmland, 0.36% converted to urban and residential land. The area of grassland in Zuli river basin decreased 0.25% from 1987-1993, respectively 0.18% of grassland converted to farmland, 0.07% to urban and residential land from 1993 to 2000. By contraries, the area of farmland in Zuli river basin decreased 2.96% from 2000 to 2005, respectively 2.94% of farmland converted to grassland, and 0.02% to urban and residential land.

Tab 2.Land-use change of Zuli River Basin

Landuse Types	1987		1993		2000		2005	
	Area(km2)	Ratio(%)	Area(km ²)	Ratio(%)	Area(km ²)	Ratio(%)	Area(km ²)	Ratio(%)
Forest	165.78	1.56%	165.69	1.56%	166.69	1.56%	167.13	1.57%
Grassland	5538.87	51.99%	5232.22	49.11%	5205.52	48.86%	5518.63	51.80%
Bottomland	10.45	0.10%	10.51	0.10%	10.54	0.10%	10.15	0.10%
Urban and sidential land	1024.26	9.61%	1028.87	9.66%	1035.74	9.72%	1037.5	9.74%
Desert land	20.46	0.19%	19.77	0.19%	19.77	0.19%	19.61	0.18%
Farmland	3893.67	36.55%	4196.65	39.38%	4214.99	39.57%	3900.04	36.61%

3.2 The spatial land use changes of three clusters in Zuli river basin

Based on the results of cluster-analysis by ten indices of natural and social characteristics, we divided the 64 towns of Zuli river basin into three ecological agriculture clusters (Fig.2). Cluster 3 is the irrigation section. It has the characteristics in land utilization of rather high cultivating ratio, town land utilization degree been rather low, the main producing area of grain and economic crops and better living and economic conditions in Zuli river basin. Cluster 2 is the dry farming agriculture distributed in gully region of Loess Plateau, and most farmland is the slop farmland with lower total grain yield, per capita yield and grain bearing capacity. Its mean precipitation amount is higher, so it has high potential to develop rainwater harvesting agriculture. Cluster 2 is the main attention points of rainwater harvesting agriculture which is flow losing of water and soil being great, and proportion of middle or low yield land being high. Cluster 1 is distributed in the plain field of Loess Plateau. It has a certain irrigated farmland, and low rate of efficient irrigation and poor irrigated condition, because of insufficient water resource. Cluster 1 is both irrigation and dry farming agriculture; the total grain yield and rural economic level are much lower than Cluster 3, but higher than Cluster 2.

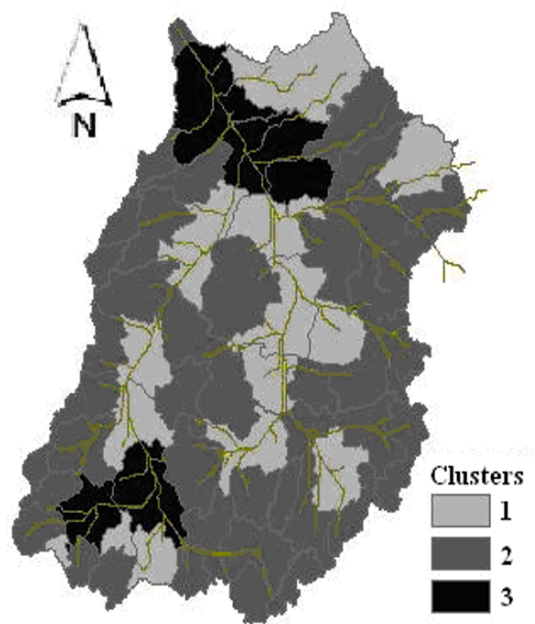


Fig 2.The three clusters of Zuli river basin

Using spatial analysis function of Arcview3.2, we overlaid the land-use maps of different temporal and different clusters, to calculate the cross-tabulation table, which was output as a transition matrix, as Table 3, 4, 5 showed.

Tab 3.Land-use change of cluster 1 in Zuli River

Landuse Types	1987		1993		2000		2005	
	Area(km2)	Ratio(%)	Area(km2)	Ratio(%)	Area(km2)	Ratio(%)	Area(km2)	Ratio(%)
Forest	61.24	1.71%	61.72	1.72%	61.37	1.71%	61.94	1.73%
Grassland	1873.09	52.26%	1791.13	49.90%	1793.29	49.96%	1862.99	51.91%
Bottomland	1.76	0.05%	1.76	0.05%	1.8	0.05%	1.76	0.05%
Urban and residential land	293.94	8.20%	299.15	8.33%	302.12	8.42%	303.16	8.45%
Desert land	9.96	0.28%	9.12	0.25%	9.12	0.25%	9.12	0.25%
Farmland	1349.99	37.67%	1426.3	39.74%	1422.18	39.62%	1350.91	37.64%

Cluster 1 in Zuli river basin: the land-use change is that farmland is continually increasing from 1987 to 2000, but decreasing from 2000 to 2005. On the contrary, grassland is continually decreasing from 1987 to 2000, but increasing from 2000 to 2005. 1987-2000 grassland area decreased 2.30%, 1.95% to farm land, and 0.22% to urban and residential land; 2000-2005, farm land of Cluster 1 decreased 1.98%, 1.95% to grassland, and 0.03% for urban residents land.

Tab 4.Land-use change of cluster 2 in Zuli River

Landuse Types	1987		1993		2000		2005	
	Area(km ²)	Ratio(%)	Area(km ²)	Ratio(%)	Area(km ²)	Ratio(%)	Area(km ²)	Ratio(%)
Forest	115.75	2.01%	113.83	1.97%	116.34	2.02%	115.75	2.01%
Grassland	3127.63	54.23%	2896.94	50.23%	2878.16	49.91%	3079.13	53.39%
Bottomland	2.19	0.04%	2.31	0.04%	2.29	0.04%	6.59	0.11%
Urban and residential land	530.05	9.19%	549.29	9.52%	553.81	9.60%	555.43	9.63%
Desert land	9.31	0.16%	9.11	0.16%	9.11	0.16%	9.11	0.16%
Farmland	1982.59	34.38%	2195.7	38.07%	2207.96	38.29%	2001.81	34.71%

Cluster 2 in Zuli river basin: the land-use change is that farmland is continually increasing from 1987 to 2000, but decreasing from 2000 to 2005. On the contrary, grassland is continually decreasing from 1987 to 2000, but increasing from 2000 to 2005. 1987-2000 grassland area decreased 4.32%, 3.91% to farm land, and 0.40% to urban and residential land; 2000-2005, farm land of Cluster 2 decreased 3.58%, 3.48% to grassland, and 0.03% for urban residents land.

Tab 5.Land-use change of cluster 3 in Zuli River Basin

Landuse Types	1987		1993		2000		2005	
	Area(km ²)	Ratio(%)	Area(km ²)	Ratio(%)	Area(km ²)	Ratio(%)	Area(km ²)	Ratio(%)
Forest	12.24	0.96%	11.31	0.89%	12.41	0.97%	12.24	0.96%
Grassland	586.85	46.05%	583.59	45.79%	579.65	45.48%	575.2	45.13%
Bottomland	0.09	0.01%	0	0.00%	0	0.00%	0	0.00%
Urban and residential land	144.79	11.36%	147.14	11.55%	149.23	11.71%	150.03	11.77%
Desert land	1.38	0.11%	1.53	0.12%	1.53	0.12%	1.38	0.11%
Farmland	529.1	41.51%	530.45	41.62%	531.21	41.68%	535.69	42.03%

Cluster 3 in Zuli river basin: the farmland continues to increase, the grass area from 1987 to 2000 reduced continually. From 1987 to 2005, the grass area reduces 0.92%, respectively, 0.40% to urban and residential land; 0.52% to farm land.

4. DISCUSSION

Zuli river basin in the administrative regionalization belongs to Dingxi and Huining County in Gansu Province. The economic level of Dingxi and Huining Country is relatively backward. Along with some human factors, such as the population increase and agricultural reclamation activity, the farmland continued to increase, and grassland continued to decrease from 1987 to 2000 in Zuli river basin. After the Policy of Converting Farmland to Forest is carried out after October 1999, the farmland area reduced obviously. Up to 2005, it basically approached to the number of farmland area in 1987.

The land use changes of three clusters in Zuli river basin are also obvious. The trends of land use changes are generally in the same in both cluster 1

and cluster 2, and they are consistent with the whole land use changes of Zuli river basin. However, cluster 3 has the different trends of land use changes. The farmland in cluster 3 is mainly irrigated. The grassland continued to reduce, but the reduction rate is much lower. The farmland continued to increase, and the rate is also low. It is the producing areas of food and economic crops and rural economy developed section in Zuli river basin, which is distributed in flat area, with agricultural irrigation and little area of returning land for farming to forestry. Cluster 2 is distributed in gully region of loess plateau, which primarily depended on rain-feed agriculture and farmland by slope farming. Total yields of grain and per capita grain are in the lowest level in Zuli river basin. The rate of converting grassland to farmland is the biggest in the whole basin. Because of the Returning Land from Farming to Forest Policy, the areas of grassland in cluster 2 increased slightly after 2000, but not reach the areas of grassland in 1987. Cluster 1 is mainly distributed in plain areas, and has a certain irrigated farmland. Because of the insufficient water resource and poor irrigated condition, growing population has added very pressure to agricultural production, Agricultural production of Cluster 1 has both dry agriculture and irrigation farming, and being of middle level among the three clusters in Zuli river basin. Total yields of grain and per capita grain are in the middle level.

We investigated the present land use situation from more than two hundred households in Zuli river basin, and over 94% of them are in support of Conversion of Cropland to Forest and Grassland Project and restoration of eco-environment in Loess Plateau. During the implementation of Conversion of Cropland to Forest and Grassland Project, the government provides a certain amount of grain and subsidy. 56% of the investigated households express that if the national subsidy is stopped, they would continue to cultivate on the slope farmland which has been already returned to the grassland. These households are mostly distributed in gully region of Loess Plateau, and depended on slope farmland. They belong to the towns of cluster 1 and cluster 2 which is also the main land use change area in the cluster analysis in this paper. The total yields, per capital of grain and grain bearing capacity are much lower.

To achieve social overall development in Zuli river basin, it is a significant study to accomplish The project of Conversion of Cropland to Forest and Grassland, as well as to make a breakthrough on regulation of agriculture structure and rural economic structure, to harmonize relations between the project and regulation, to advance ecological environments and improve rural economic development in the whole basin. Based on the above principles, we divided the whole basin into three clusters:

(1) Cluster 1 is the mainly land use change area, and its cultivation is mainly distributed in the slope farmland. It is mostly affected by the Conversion of Cropland to Forest and Grassland Project. This cluster should

adjust of structures between farmland and grassland, and the improvement of water-using efficiency.

(2) Cluster 2 is also the mainly land use change area, and its annual precipitation is the highest in three cluster. It is the key cluster to develop rainwater harvesting agriculture and has high potential of water resource to develop high-efficiency agriculture.

(3) Cluster 3 is the irrigated agriculture area which is little affected by the Conversion of Cropland to Forest and Grassland Project. Its annual precipitation is much lower, so Cluster 3 has no enough precipitation to develop rainwater harvesting agriculture. Developing high efficient irrigated cultivation is the key stratagem in this cluster.

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THE CHANGE OF LAND COVER/LAND USE IN EJINA OASIS OVER 20 YEARS

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Abstract: Land use and land cover change have been of great concern in global change research in recent years. Base on comparison with the remote sensing data in 1982 and 2000 and field investigation, the results of land cover and land use change were obtained by the method of landscape analysis. Ten types of land use were identified: riparian woods, riparian shrubbery, desert shrubbery, desert grassland, river-way and water area, salinised land, town, Gobi, shift sand dune, denudative upland. The results show that, (1) there were obvious Changes in land cover structure. The area of riparian woods decreased 0.97% and the number of patch decrease 376; The area of riparian shrubbery increased 0.92% and the number of patch decreased 1316. Meanwhile, the index of %LAND of desert shrubbery increased from 4.49% to 5.65%; Because of decrease of water quantity of discharge from middle reach. The patch of river-way and water area decreased from 40 to 6. The index of % LAND decreased 0.15%. At the same time, the index of % LAND of shift sand dune increased 0.42%. (2) the area of riparian woods dominated by *Populus euphratica* and desert grassland decreased to 45.02% and 14.55%. However, the areas of riparian shrubbery dominated by *Tamarix* spp and desert shrubbery increase to 35.03% and 25.88%. The transition probability is 45.95% from riparian woods to riparian shrubbery. at the same time, they are 0.78% and 3.01% from riparian woods to desert→shrubbery and desert→grassland. The succession trend of ecosystem was obtained: riparian woods riparian shrubbery and grassland desert grassland. Meanwhile, the succession velocity becomes higher and higher.

Key words: Ejina oasis, land ecology, Spatial distribution

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Land Use/Land Cover Change, LUCC is noticed in current international research area, was set for core project by international Geosphere and Biosphere Project programme (IGBP) and International Human Dimensions Programme (IHDP) (Tuner II B L.,1990; Meyer W B, et al., 1994). It is quite important in global or local environment changes and continual development. Land use and land cover change is the most intimate question between nature and human, it is the embodiment of relationship of human being and earth. Water, soil, air, biology and topographic condition are the main compositions of region ecological environment, which change and interact each other, determinate region land ecology types and evolution characteristic (Jorgenson M T, 1999; Wang Genxu, et al., 2001). With the higher development of the satellite remote sensing technology and space information system, there are great progresses in quantitative investigation between the spatial feature of land surface with modern process, which analyzed the driving factors of ecological environment variation, and provided quantification's research approach for ecological environment protection and construction program (Li Xiubin. et al., 1996; Shi Peijun, et al., 2001). Landscape change equal to land translate in many situations, it include land use and land cover change, which are the main base to divide landscape, and landscape heterogeneity which has intimate relationship with land beset. It will be more and more important to research land retirement and vegetative cover succession for region ecological environment in landscape ecology.

Ejin locates at the catchment area of Heihe River, it is in the most western of Nei Mongolia autonomous region, the total area is 114.6 thousand km². Ejin is a animal husbandry border county where the Mongolia Race of Torguts tribal descendant is main part. Total population only 15.7 thousand , among of which agro-animal husbandry population is 3.5 thousand. Ejin oasis is located flat basin in the middle of Ejin. The upstream water of Heihe River is alone water source which maintains Ejin oasis. As a result of the middle reaches of Heihe River over-development and over-utilize water resource, taking the land desertification, the vegetation degenerates as representative's ecological environment worsen has affected seriously the downstream desert oasis and restricts economy of river basin and society's sustainable development. Ejin ecological environment has been worsened, it includes the blocking the flow, the terminal lake vanished, the lowering of groundwater table, the vegetation degeneration, the natural oasis withering, the land desertification rapid development, the sand source appearing in oasis interior, the sand storm aggravating harm. Not only this causes the region environment to worsen and the biological species reduction, but also has threatened the entire river basin and the peripheral localities ecological security and the environment condition. Because the strategic status of Ejin to be special, therefore we must research the inner

link between the water resources and the oasis, rescue Ejina oasis, control ecological environment in the round, it will be significant and the profound significance for the border area stable, the territorial integrity, the national unity as well as west develops.

1. THE GENERAL SITUATION OF RESEARCH REGION AND THE APPROACH

1.1 The general situation of research region and ecology type division

This scope of research region is: Ejina oasis approximately situates between 99°03' - 100°00' E, 40°30' - 42°30' W, is a part of Alashan Platform, is a large alluvial fan of the termination of Heihe River. Its east is close to Badain Jaran Desert, west is the Mazong mountainous region, north to the Chinese and Mongolian boundary, south to Dingxin Oasis whose area is 31.2 thousand km² at the upper extreme of Heihe downstream. According to the ecology region division, it belongs to the temperate zone warm temperate zone arid desert area Alashan High Plain sub-region. Arid is the basic climate characteristic in this region ecosystem, also is the region unique ecosystem structure. Based on the land ecosystem division principle, the oasis ecological environment system may be divided: The riparian forest ecosystem including riparian woods which *Populus euphratica* is main part and riparian shrubbery which *Tamarix* SPP is main, it occupies 4.7% of the oasis area; Desert steppe ecosystem including the desert shrubbery and the desert steppe, it accounts for 16.3%; The water area, including the seasonal rivers and the lake, accounts for 0.2%; Other difficultly to use land, including Sandy land, Gobi, salina land and low hill, accounts for 78.8%.

Populus euphratica, *Elaeagnus angustifolia*, *Tamarix* sp., *Phragmites communis*, *Achnatherum splendens*, *Sophora alopecuroides* and *Glycyrrhiza uralensis* etc.; psammobiontic shrubs and herbs mainly occur in the surrounding desert region of the oasis, they include *Haloxylon ammodendron*, *Hitratria tangutorum*, *Artemisa* sp. and *Agriophyllum arenarium* etc.; in the arid low mountain hilly areas and vast gobi plain there are sparse drought-tolerant desert vegetation such as *Reaumuria soongorica*, *Nitraria sphaerocarpa*, *Ephedra przewalskii*, *Zygophyllum xanthoxylon*, *Sympegma regelii*, *Anabasis* and *Calligonum* sp. etc.

Table 1 the spatial distribution characteristic of oasis and desert in the Ejn

NAME	Type	Basic feature	Distribution-phore
	Riparian forest	Including Populus euphratica forest, Populus euphratica and Tamarix SPP shrubery which the form is priority part, Sophora alopecuroides and weed as constructive species and Lycium ruthenicum , Karelina caspica in partial place. its structural features are severally arbour rarity and the age of forest is old, shrubery live densely, while hassock is short. Taking Populus euphratica and Tamarix SPP forest as typical representative.	Distribute by the spot or the corridor form in the oasis interior river-way both sides, assumes flabelliform, occupies the oasis area 4.7%, is the main body of the oasis.
	Ecosystem	The middle Gobi locates between the west and east river, takes the rarity old age Populus euphratica as primary, there are Reaumuria soongorica, Haloxylon ammodendron and Nitraria tangutorum under it, only rarity Nitraria sphaerocarpa, Calligonum sp.in other places, Tamarix sp. and Phragmites communis in lowland and on lacustrine beach with good moisture condition; Take rarity Nitraria tangutorum and Reaumuria soongorica as typical representatives.	This type occupies the oasis area 16.3%, by belt-shaped or mottling distribution, in far away river-way Gobi is the rarity grassland, Phragmites communis mainly distributes in Guriner Beach.
	Waters area	The area of West Juyan Lake is 266km ² , East Juyan Lake is 336 km ² , some small lakes and seasonal river-ways. West Juyan Lake have withered 63 years, sometimes there are few excess water in other lakes.	West and East Juyan Lakes locate in the most north of the oasis, other lakes in the east and west of the oasis.
	Other difficultly to utilized land km ²	The raleitive heights of Fixed, half-fixed sand dune are smaller than 20m, there are rarity tamarix sp; the cover degree of vegetable in Gobi is below 3%, there are xeric, extra-xeric Reaumuria soongorica and so on, there is short life Shacong and so on in less than 100m denudative upland.	Gobi mainly distributes in the oasis periphery, but fixed and half-fixed sand dune mainly distribute in both sides of river-way and the inner of the oasis, the denudative upland distributes in Hongger of eastern and the northwest Fox mountain. The beach is the salification meadow soil of Guriner Lake.

1.2 Research approach

Mainly contrasted and has analyzed the different time remote sensing data and auxiliary by field investigation. Using Landsat TM/ETM remote sensing data is a kind of effective method about region Land use/Land cove

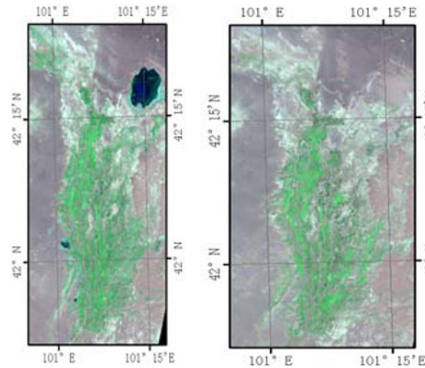


Fig 1 : Remote sensing image of Ejina oasis in 1982 and 2000

2. SPATIAL DISTRIBUTION AREA CHANGES OF DIFFERENT LAND COVERS

2.1 Riparian forest ecosystem Change

The Riparian forest ecosystem is composed by two parts, one is *Populus euphratica* forest and riparian woods, which *Populus euphratica* is as primarily, but *Russianolive* or *Tamarix* SPP as the auxiliary; Two is riparian shrubbery, including rarity old age *Populus euphratica* and densely living *Tamarix* SPP or *Tamarix* SPP shrubbery. During 1982-2000, the area of woods seriously shrunk, reduced 1063.0 hm^2 , annual decline rate is 2.51% in the appraisal year, the overmature forest increased unceasingly in the age of forest structure, sickness and mouldered woods and survives woods increased in the forest form structure. In contrast riparian shrubbery increased, expanded from 2862.5 hm^2 to 2865.2 hm^2 , the average increment rate is 1.95% yearly. The riparian forest ecosystem has had the change. This expressed that the riparian forest made from arbor, shrub and grass is inverting to riparian shrubbery composed from shrub and grass. The riparian forest ecosystem structure and function is tending towards simple.

2.2 Desert steppe ecosystem change

Desert steppe ecosystem is composed of desert shrubbery and desert grassland. steppe ecosystem be ejin oasis' s important constituent, in the near 20 years, desert shrubbery has increased greatly. But the area of desert grassland reduces unceasingly, achieves 12315.2 hm^2 , the reducing rate of annual mean is 0.81%, the whole area of desert steppe reduces 4.3%, about

824.6hm², is 1.44%, achieves 1272 hm². But the area of desert grassland reduces unceasingly, achieves 12315.2 hm², the reducing rate of annual mean is 0.81%, the whole area of desert steppe reduces 4.3%, about 824.6hm². Ecosystem structure tends towards simple.

2.3 Water area change

The water area includes mainly lake and the river-way. The river is divided into two big branches at Langxin mountain in Ejin oasis, and could be divided 19 branches furthermore. These branches all are the seasonal rivers, can form runoff in flood period or in the winter every year, other period all are the withered river beds, becomes source region of the sand storm. There are 7 lakes In 1982, among which the waters area of the east river' s terminal lake is 99 hm², other lakes area is 68.4 hm². In later 20 years, the lakes are successively withered, in the lake base, became the Saline-alkalization sand, in the lake edge, became the mobile sand.

2.4 Land system of difficult to utilize change

It can reveal the region ecological environment condition and the evolution direction directly with difficult to utilize land type change; Its increment is the manifestation of land serious degeneration. The land of difficult to utilize area increased continually in the near 20 years. So we can see that the shift sand dune area increased from 762.8 hm² to 1226.1 hm², changed 463.3 hm², the annual mean increment is 3.37%; Secondly, the land of villages and towns increased, which took up the forest land; Next salinised land was reducing, the accumulation reduced was 69.9 hm², because the original salina land had changed into the wind erosion sand by the nature through 20 years.

Table 2:The direction and extent of oasis types transfer in the Ejina

Land Use	1982	2000	1982-2000	Average increase rate (%)
Riparian Woods	2361.2	1298.2	-1063.0	-45.02
Riparian Shrubbery	2862.5	3865.2	1002.7	35.03
Desert Shrubbery	4917.2	6189.9	1272.7	25.88
Desert Grassland	14412.6	12315.3	-2097.3	-14.55
River-way and Water area	177.4	12.9	-164.5	-92.73
Salinised Land	84.9	15.0	-69.9	-82.33
Town	34.8	46.5	11.7	33.62
Gobi	83716.3	84363.0	646.7	0.77
Shift Sand Dune	762.8	1226.1	463.3	60.74
Denudative Upland	256.8	256.8	0	0.00

3. LAND ECOTYPE EVOLUTION

3.1 Dispersal area and structural change of land covers

The %LAND index (Landscape quadrat area ratio) could display the structural changes of the landscape spatial distribution, The %LAND index changes of land covers in Ejina oasis is showed in table 3.

Table 3: The %LAND in index changes of different land cover types of Ejina oasis in 1982-2000

Land Use	1982		2000	
	PATCH	%LAND	PATCH	%LAND
Riparian Woods	1888	2.15	1512	1.18
Riparian Shrubbery	4266	2.61	2950	3.53
Desert Shrubbery	6454	4.49	5680	5.65
Desert Grassland	12615	13.15	11976	11.24
River-way and Water area	40	0.16	7	0.01
Salinised Land	34	0.08	64	0.01
Town	6	0.03	6	0.04
Gobi	5842	76.39	4910	76.98
Shift Sand Dune	12	0.7	8	1.12
Denudative Upland	8	0.23	8	0.23

We could see from table 3, the Gobi took up the leadership of spatial distribution, its status didn't change, still occupied 76.39%~76.98% of the oasis area. In the recent 20 years, riparian woods area shrunk 0.97%, the patches decreased 376, but riparian shrubbery increased 0.92%, the patches decreased 1316; The patches of desert shrubbery and desert grassland decreased unceasingly, but the %LAND index of desert shrubbery increased from 4.49% to 5.65%; Because the water inflow from middle reaches decreased sharply, the patches of river-way and water area decreased from 40 to 6, the %LAND index decreased 0.15%. The %LAND index of shift sand dune increased 0.42% at the same time. Although there wasn't big change in oasis spatial pattern, the riparian forest-sparse shrub-grass structure tended to simple, its ecology function weakened.

3.2 Ecosystem types shift and change characteristic

Using 1982 and 2000 remote sensing data, has established the transfer matrix of recent 20 years. The matrix element expressed one kind of landscape divert to another kind of landscape in area proportion. The diagonal value represents area ratio of landscape with self-successive, so we could intuitively see landscape dynamic evolution tendency and the evolved range. The oasis landscape have been diverting to desert landscape in recent

20 years in Ejin oasis. The transition probability from riparian woods and shrubbery to riparian shrubbery and grassland was as high as 45.95%, to desert shrubbery and rarity grassland were 0.78% and 3.01%, to Gobi Landscape was 10.87%; the transition probability from riparian shrubbery and grassland to riparian woods and shrubbery was 8.06%, but to desert shrubbery and rarity grassland were 10.95% and 19.64%, to Gobi was 11.88%; the transition probability from rarity shrubbery to rarity grassland was 21.19%, to Gobi was 3.96%; the transition probability from large area rarity grassland to rarity shrubbery, riparian shrubbery and grassland and riparian woods and shrubbery were 14.05%, 3.36%, 0.23% respectively, but to Gobi was 28.13%。The transition probability from river-way and water area to the vegetative landscape was far and away less than to Gobi(desertization) through 20 years evolvement. It can be seen from above data, Ejin's ecology condition was improved in partial and small scope from 1982 to 2000, the whole worsened condition (seeing Table 4).

Table 4 : The director and extent of oasis type trans of Ejin in 1982—2000

1982	2000									
	Riparian Woods	Riparian Shrubby	Desert Shrubby	Desert Grassland	River-way and Water area	Salinised Land	Town	Gobi	Shift Sand Dune	Denudative Upland
Riparian Woods	39.19	45.95	0.78	3.01	0.03	0.06	0.1	10.87	0	0
Riparian Shrubby	8.06	49.13	10.95	19.64	0	0.11	0.09	11.88	0	0
Desert Shrubby	0.16	1.9	72.54	21.19	0	0.02	0	3.96	0.22	0
Desert Grassland	0.23	3.36	14.05	53.57	0	0.01	0.03	28.13	0.61	0
River-way and Water area	1.35	4.89	4.53	26.73	5.73	0.18	0.31	56.04	0.21	0
Salinised Land	0.13	1.29	6.72	50.06	0	0.23	0	41.56	0	0
Town	0.67	1.05	0	0	0	0	98.14	0.03	0	0
Gobi	0.12	0.93	0.3	3.38	0	0.01	0	94.82	0.44	0
Shift Sand Dune	0	0	0	0	0	0	0	0.48	99.44	0
Denudative Upland	0	0	0	0	0	0	0	0	0	100

4. CONCLUSION AND DISCUSSION

In the recent 20 years, the water volume drained at the beginning of 80's was 1.174 billion m³/a, but at the end of 80's was 0.844 billion m³/a, the mean drainage was 0.378 billion m³/a in the 90's, only was 0.283 billion m³ in 2000. At the same time the stock capacity of oasis and desert rangeland was maintained at 24×10⁴~29×10⁴ sheep, the overload was 4×10⁴~4×10⁴ sheep in Heihe River. The water volume drained continually decreased, it made that the ecological environment worsened unceasingly, the land use and the land cover had changed fiercely. This became the factor which

rangeland overloaded continually. Mainly displays in: (1) The riparian woods and desert rarity grassland decreased 45.02% and 14.55%; (2) The rivers blocked the flow in long time, which caused the lake quantity and the water area decreased sharply, turned into desertification land; (3) Riparian forest and grassland decreasing, caused the shift sand dune area Increased, the annual mean increase was 3.37%. Through the evolution trend, the range and the land cover %LAND index change, it can be seen that the spatial evolution characteristic of land cover in the recent 20 years. The 60% of riparian woods and shrubbery which occupied the main part in oasis have changed, the 50% of shrubbery and grassland have changed, the 27% of rarity shrubbery and 47% of rarity grassland have also changed, which occupied larger area in oasis, the water area evolved toward the non-plant growth type. Looked from the overall landscape, the evolvement of Ejina oasis is riparian woods and shrubbery→ riparian shrubbery and grassland→ desert rarity shrubbery→ desert rarity grassland→ Gobi.

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ASSESSMENT AND MAPPING OF HEAVY METALS POLLUTION IN TEA PLANTATION SOIL OF ZHEJIANG PROVINCE BASED ON GIS

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Abstract: According to the 2nd grade (pH<6.5) of GB1516-1995, Inverse Distance Weighted interpolation method of GIS, single and Nemerow's synthetic pollution indexes were used to assess and map heavy metals pollution in tea plantation soil of the primary tea producing area in 12 counties of Zhejiang Province. It was indicated by using exploring statistics and assessment map of single pollution index that contamination of Cd was the highest, followed by Ni, As and Zn, while the contaminations of Cr, Cu, Hg and Pb were all zero; almost all of the tea soil were unpolluted by Cr, Cu, Hg and Pb, and few was slightly polluted by As, Cd, Ni and Zn. Moreover, it revealed on the assessment map created from Nemerow's synthetic pollution indexes that 160 samples were located in the safety domain, 12 samples were located in the precaution domain and only 7 samples were slightly polluted; up to 93% of the whole study area was belonged to safety domain, 6.5% was the precaution domain, whereas only 0.50% area was the slightly polluted domain.

Keywords: heavy metals pollution, tea plantation soil, assessment and mapping, GIS

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1. INTRODUCTION

Zhejiang Province is one of the leading tea producing area in China with a planting area of 159,700 ha(Xu,2004; Huang,2005).The heavy metals pollution was the most important one of the primary three factors affected tea quality safety of Zhejiang Province (Yu, 2005). The heavy metals contents in tea was postively correlated to the one in tea soil(Shi et al., 2003; Wu et al., 2002). Since a survey of soil heavy metal contents might supply some fundamental information for the environmental assessment, extensive investigations of soils had been carried out in some countries and regions in recent years (Elsokkary et al., 1995; Adamo et al., 2003) and some works also had been carried out to evaluate the heavy metal contamination in China(Li et al., 2001; Wang,2002). However,there was few detailed and systematically studies undertaken to investigate the heavy metal contents in tea plantation soil coupling GIS with single and Nemerow's synthetic pollution indexes in China.The main objector of this inverstigation was to: (1) assess the heavy metals pollution of tea soil in Zhejiang by single and Nemerow's synthetic pollution indexes;(2) make assement maps of heavy metals by GIS sptail interpolation and drawing technologies.

2. MATERIALS AND METHOD

2.1 Study area

The tea producing area of Zhejiang Province were devided into three predominant domains of east,south and west of Zhejiang by the Regional layout and programming of characteristic and predominant agriculture products in Zhejiang Province(2003-2007) (Huang, 2005).12 counties were picked out as the study area of this inverstigation.

2.2 Soil sampling and analysis

A total of 179 soil samples were collected from tea plantation of 12 counties in Zhejiang Province(Fig.1). A Trimble Pro-XR Global Positioning System (GPS, Trimble,USA) was used to locate each sampling point to within ± 5 m. Composite soil samples were taken from each of these sampling points. Using quincunx-sampling method, 5 soil cores were collected to a depth of 0.2 m in a 25-m rectangle of each grid node, and then bulked to give a composite sample.

Soil samples were air-dried at 30°C and sieved through a 0.002-m polyethylene sieve. After digestion with a mixed acid of aqua fortis, nitric

acid (HNO_3), fluorin acid (HF) and chlorine acid (HClO_4), heavy metal contents were determined according to the national standard methodologies (NSPRC, 1995). Concentrations of Cd, Pb, Cu, Cr, Ni and Zn were determined using an inductively coupled plasmamass spectrometry (ICP-MS; POEMS 3,Thermo Electron,USA).Applying atomic spectrofluorophotometer (AFS,XGY-1011A,IGGE,China) to detect the concentrations of As,Hg. Standard reference material,GSS-1 soil was obtained from the Institute of Geophysical and Geochemical Prospecting, Department of Geology and Minerals of China,was used as quality assurance measure for the analyses of total heavy metals and incorporated during the analysis.



Fig. 1: Sampling points and study area

2.3 Data analysis

Single and Nemerow's synthetical pollution indexes were applied to assess soil environmental quality in previous study (Liu et al., 2004). In the present study, these two were utilized for the degree of soil environmental pollution and integrative assessment of soil environmental quality, the 2nd grade($\text{pH}<6.5$) of Standards Soil Environmental Quality (GB 15618-1995) (NSPRC,1995) was used as soil quality assessment criteria. Its equation was as follows:

$$P_n = \sqrt{\left(\text{Max}P_i^2 + \bar{P}_i^2 \right) / 2} \quad (1)$$

where

$$P_i = C_i / S_i \quad (2)$$

where, P_n is the Nemerow's synthetical pollution index; P_i is the single pollution index of the i th heavy metal, if $P_i \leq 1$, soil is safe; if $P_i > 1$, soil is polluted by the i th heavy metal; the greater the P_i is, the heavier the pollution is. C_i is the measured concentration of the i th heavy metal, S_i is the required standard of the i th heavy metal, $\bar{P}_i$ and $\text{Max}P_i$ is the average and the

maximum value of the pollution indices of the *i*th heavy metal.

The Nemerow’s synthetical pollution index P_n for all the soil sampling points was calculated to show the relative magnitudes of soil pollution. Higher P_n value indicates more serious pollution. According to GB15618-1995, soil environmental quality was classified into 5 grades from Nemerow’s synthetical pollution index, which are presented in Table 1.

Table 1. Classification criterions for polluted index of soil enviroment quality

Grade	Synthetical index	Appraisal result
1	$P_n \leq 0.7$	Safety domain
2	$0.7 < P_n \leq 1.0$	Precaution domain
3	$1 < P_n \leq 2.0$	Slightly polluted domain
4	$2 < P_n \leq 3.0$	Moderatey polluted domain
5	$P_n > 3.0$	Seriously pllouted domain

IDW interpolation method is based on a basic principle of geography that things close to one another are more alike. IDW is used to create a continuous surface from sampled point values by Using ArcGIS Spatial Analyst(ESRI,2004) in current study, the assessment maps of single pollution index were generated from single polltion index of each of eight heavy metals in all sampled points respectively, and soil environmental quality map was generated from all sampled points with Nemerow’s synthetical pollution index.

3. RESULTS AND DISCUSSION

3.1 Heavy metal concentrations in tea soil

Exploring statistics of eight heavy mentals were summarized in table 2. Based on the 2nd grade(pH<6.5) GB 1516-1995, the allowed values for these heavy metals were also listed.

Table 2. Heavy metal concentrations of tea soils in Zhejiang Province (mg/kg)

	As	Cd	Cr	Hg	Pb	Zn	Cu	Ni
Range	2.7-65.6	0.06-0.47	10.0-121.0	0.007-0.211	13-75	28-516	4.3-53.8	4.2-56.9
Mean	10.10	0.14	55.51	0.04	29.91	71.98	19.19	18.61
Minimum	2.70	0.06	10.0	0.01	13.0	28.0	4.30	4.20
Maximum	65.60	0.47	121.0	0.21	75.0	516.0	53.80	56.90
Pover	1	9	0	0	0	1	0	5
Tover(%)	0.559	5.028	0	0	0	0.559	0	2.793
Threshold	40	0.30	150	0.30	300	200	150	40

Pover: points abover threshold; Tover: total percentage above threshold

As shown in the table, the average concentrations of As, Cd, Cr, Hg, Pb, Zn, Cu and Ni were all below the allowed values of GB 1516-1995. With respect to the total percentage (Tover) of above this allowed limits, contamination of Cd was the highest, which reached to 5.028%, followed by Ni, As and Zn; contaminations of Cr, Hg, Pb and Cu were the lowest, which were all zero.

3.2 Assessment and mapping of heavy metals pollution by single pollution index

3.2.1 As

Contamination of As ranged from 2.7 to 65.6 mg/kg and mean value was 10.10 mg/kg which was lower than the threshold(30 mg/kg). There was only 1 sample which single pollution index of As was a little greater than 1.0. It was to say that this sample was polluted by As.

A spatial distribution map of As contamination in study area was shown as Fig.2. It revealed that almost all of the tea soil in study area was absolutely safe and only few was slightly polluted by As.

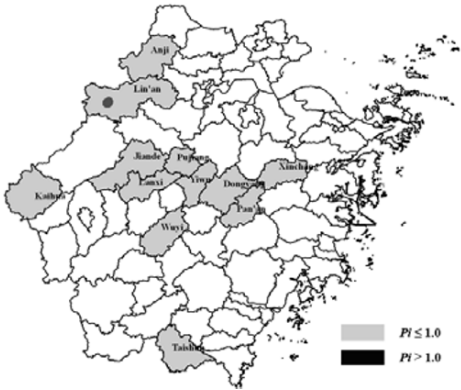


Fig.2: Spatial distribution map of As

3.2.2 Cd

Contamination of Cd ranged from 0.06 to 0.47 mg/kg and mean value was 0.14 mg/kg which was lower than the threshold(0.60 mg/kg). There was 9 samples which single pollution index were greater than 1.0. It was to say that there was 5.028% of soil samples polluted by Cd.

A spatial distribution map of Cd contamination in study area was shown as Fig.3. It revealed that most of the tea soil in study area was safe and only few was slightly polluted by Cd.

3.2.3 Zn

Contamination of Zn ranged from 28 to 516 mg/kg and mean value was 71.98 mg/kg which was lower than the threshold(250 mg/kg). There was only 1 sample which single pollution index was greater than 1.0. It was to say that there was only 0.559% of soil samples polluted by Zn.



Fig.3: Spatial distribution map of Cd

A spatial distribution map of Zn contamination in study was shown as Fig.4. It revealed that most of the tea soil in study area was safe and only few was slightly polluted by Zn.

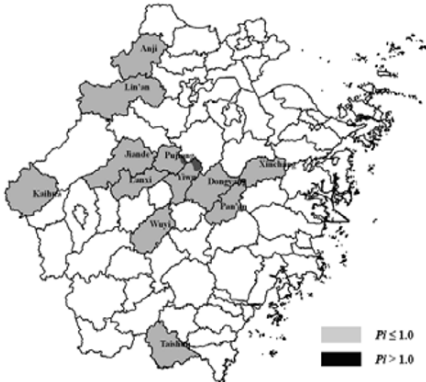


Fig.4: Spatial distribution map of Zn

3.2.4 Ni

Contamination of Ni ranged from 4.2 to 56.9 mg/kg and mean value of Ni was 18.61 mg/kg which was lower than the threshold(50 mg/kg).There was 5 samples which single pollution index were greater than 1.0.It was to say that there was 2.793% of soil samples polluted by Ni.

A spatial distribution map of Ni Contamination in study area was shown as Fig.5.It revealedthat most of the tea soil in study area was safe and not polluted and only few was slightly polluted by Ni.

3.2.5 Cr,Hg,Pb,Cu

Contamination of Cr ranged from 10.0 to 121.0 mg/kg and mean value of Cr was 55.51 mg/kg which was lower than the threshold(200 mg/kg), contamination of Hg ranged from 0.007 to 0.211 mg/kg and mean value was 0.04 mg/kg which was lower than the threshold (0.50 mg/kg), contamination of Pb ranged from 13 to 75 mg/kg and mean value of Pb was 29.91 mg/kg which was lower than the threshold(300 mg/kg), contamination of Cu ranged from 4.3 to 53.8 mg/kg and mean value of Cu was 19.19 mg/kg which was lower than the threshold(100 mg/kg).

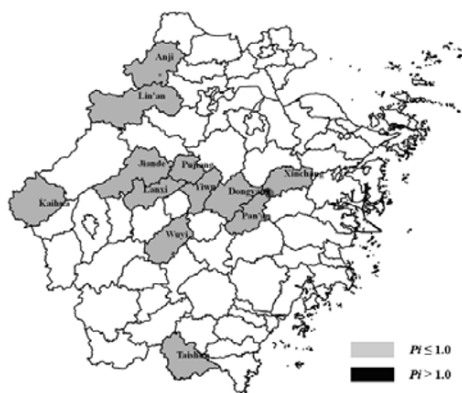


Fig.5: Spatial distribution map of Ni

There exist no sample which single pollution index of Cr, Hg, Pb or Cu was greater than 1.0.It was to say that all of soil samples were unpolluted by Cr, Hg, Pb or Cu.

The spatial distribution maps of Cr, Hg, Pb and Cu contamination in study area was shown as Fig.6. It revealed by all maps that all of the tea soil in study area was safe from Cr, Hg, Pb and Cu.

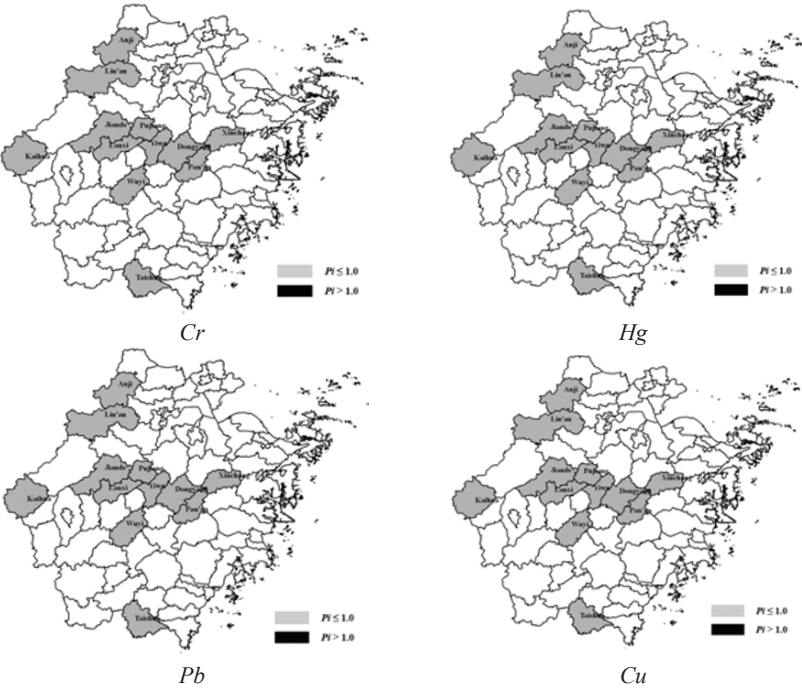


Fig.6: Spatial distribution map of Cr, Hg, Pb, Cu

3.3 Assessment and mapping of heavy metals pollution by Nemerow synthetic pollution index

The assessment map of heavy metals pollution in study area was illustrated in Fig.7, which created from the Nemerow’s synthetical pollution index of all tea soil sampling points .

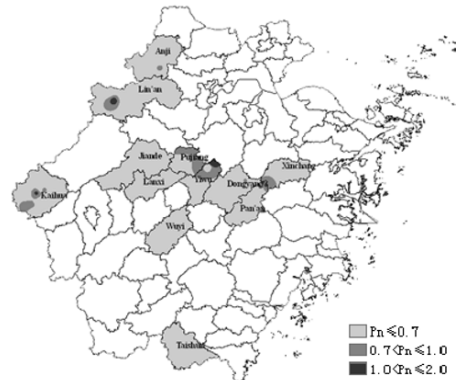


Fig. 7: Assessment map of tea soil environmental quality of Zhejiang Province

It should be noticed that the interpolated surface were only generated in 12 counties where soil sampling points were collected. As shown in Fig.7, up to 93% of the whole study area belonged to the safety domain, 6.5% belonged to the precaution domain, whereas only 0.50% area was slightly polluted domain. Summarized with the whole 179 samples, 160 samples were in the safety domain in which the soils were considered as unpolluted, 12 samples were located in the precaution domain in which heavy metals were accumulated in agricultural soils but below the allowed limits and only 7 samples were slightly polluted, respectively. In other words, almost all of tea soil in study area was not contaminated with these heavy metals.

4. CONCLUSIONS

According to the 2nd grade (pH<6.5) of GB1516-1995, IDW interpolation method of GIS, single and Nemerow synthetic pollution indexes were used to assess and map heavy metals pollution in tea soil of primary tea producing area in 12 counties of Zhejiang Province.

By using exploring statistics and assessment map of single pollution index of eight heavy metals, with respect to the total percentage of above the allowed limits, contamination of Cd was the highest, which reached 5.028%, followed by Ni, As and Zn, contaminations of Cr, Hg, Pb and Cu were all zero. Almost all of the tea soil of study area was safe and unpolluted by Cr, Cu, Hg and Pb and few was slightly polluted by As, Cd, Zn and Ni.

By utilizing the Nemerow's synthetical pollution index, coupled with IDW, the tea soil environmental quality of 12 counties of Zhejiang Province was assessed. It revealed that 160 samples were in the safety domain, 12 samples in the precaution domain and only 7 samples were slightly polluted. According to the assessment map of tea soil environmental quality, up to 93% of the study area was belonged to safety domain, 6.5% belonged to the precaution domain, whereas only 0.50% area was slightly polluted domain.

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APPLICATION AND ESTIMATION OF WHEAT PRODUCTION EMULATION SYSTEM IN HEBEI PROVINCE

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Abstract: In according with wheat ecophysiological characteristics, the author applied technologies of system engineering method, crop simulation and computer to build wheat developing process cooperative models including growth model, developmental phase models, water balance model and nitrogen balance model etc. with the support of basic data such as variety characteristics, weather data, soil level and cultivation management, then further constructed Wheat Production Emulation System (WPES) with several additional functions such as determining variety characteristic parameters, deciding the planting design, simulating wheat phenology stages and production features, warning of the nitrogen leaching in advance, simulating the water and nitrogen deficit degree and wheat growth three-dimensional display. This system was validated and calibrated through actual experiment for four wheat growing seasons in Hebei province. Predicted yield and biomass were significantly correlated with observed data ($R^2 > 0.47$), and the Root Mean Square Error were 5.89% and 8.94% of its observed average yield and biomass. The results verified its strong mechanism and prediction performance as well as its universal adaptation.

Keywords: winter wheat, emulation system, growth and development, simulation model

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1. INTRODUCTION

Growing with the development of computer technology, system analysis theory and agricultural scientific research, crop simulation model has been becoming the core of agricultural production management and resource optimization management, and the basis of precision agriculture which is implemented now in China. After 50 years evolvement crop simulation model becomes more mature possesses of more mechanism. America, Holand, England and Australia developed many crop models, some of which had been used in agriculture successfully. DSSAT of America including many famous models such as CERES and GROPGRO etc. can simulate 17 crops, and GROPGRO can evaluate the effect of more than 20 insect pests (Hoogenboom, et al, 1999). APSIM developed by Australia integrates different crop models to a common platform using for reference among subjects, and can simulate crop, vegetable and weed etc. (McCown, et al, 1996). Wageningen Univerdity and Research Center exploited SUCROS series models including MACROS, BACROS and WOFOST model. Besides the EPIC model can evaluate climate change and its effect on agriculture (Williams, et al, 1989). In the process of model application, model validation is an important work. Many researcher have done a lot of experiments and simulations in model test, introduction and modification. Malone and Heilman (2007) appraised the Root Zone Water Quality Model (RZWQM) response to different N management strategies, and results indicated RZWQM model can quantify the effects of nitrogen management on corn yield and nitrate concentration after calibration and thorough testing, and Predicted corn yield and nitrate-N concentration were significantly correlated with observed data, and the author thought planting wheat following corn and soybean may reduce N loss. A cropping system simulation model (CropSyst) was evaluated by Benli et al (2007) for its ability to simulate growth, biomass, grain yield and evapotranspiration (ET) of wheat sown early with supplemental irrigation. Results showed its good forecast performance, and model predicted better the seasonal ET under full supplemental irrigated conditions than under rainfed conditions. The model was run to simulate supplemental irrigation and rainfed yield using 20 years weather data. Data showed wheat grain yield could be improved with applying water, and yield increase depended on irrigation time.

Now crop simulation model mainly is used to forecast yield with typical application such as studying world food and agri-ecological belt, forecasting regional yield, evaluating the effects of environment and social economy changes on agriculture. Crop model develops for multi application with the increase of social demand. Moriondo et al integrated NDVI data taken from satellite platforms and wheat development stages model (CROPSYST) to estimate regional yield. The application results obtained in two Italian provinces showed the high accuracy of the method in estimating wheat yield

at the provincial level (Moriondo, et al, 2007). Greenwald et al introduced TUV model to crop productivity model (CERES) to calculate photosynthesis active radiation (Greenwald and Bergin, 2006). The model InfoCrop integrated from many submodels can simulate crop growth, development stages, water and nitrogen balance as well as the effect of temperature, waterlog, frost, plant diseases and insect pests and greenhouse gas such as CO₂, CH₄, N₂O (Aggarwa et al, 8). Along with the study of crop model increasingly day by day, forecast for diseases and insect pests attracts more and more attention. Some information system in America and Europe can be used for investigating and predicting insect pests. Holand and Germany specially developed wheat plant protection decision-support system EIPRE and PRO-PLANT (Forrer, 1992; Frahm, et al, 1993). A simulation model of weed growth and competition was developed and parameterised for 15 autumn germinating weed species common in UK by Storkey and Cussans (2007), which was validated over 2 years and used to explore possible management options for reconciling the conservation of in-field biodiversity with winter wheat production. There were large differences in the model parameters between the species and the hypothesis that weed growth and competition could be modeled on the level of weed functional group was rejected.

China started crop simulation model study since 1980s. After introducing, analyzing and improving foreign crop models, researchers developed a lot of application systems. Some units exploited their own crop simulation model. For example, Zhao chunjiang et al (1997) constructed wheat management expert system based model for Beijing; Soil and Fertilizer Institute of Chinese Academy of Agricultural Sciences developed wheat and maize optimal fertilization expert system of Yucheng county on Huanghuai Plain; Nanjing Agricultural University integrated wheat growth model and expert system to wheat intelligent management and decision-making system (Zhu, et al, 2004); Jiangsu Academy of Agricultural Sciences constructed rice cultivational simulation-optimization-decision making system (Gao, et al, 1992). On the basis of past researches (Li, et al, 2007) and studying wheat development discipline deeply, Wheat Production Emulation System based on cooperative models was built using system engineering theory, computer technology and modeling method in order to realize digital wheat production management.

2. WHEAT PRODUCTION EMULATION SYSTEM

Based on the past studies, we collected related literatures and agronomic expert information in a large scale, then designed wheat cooperative models

in accordance with wheat growth and development discipline, and combined the models with corresponding database and repository, and constitute Wheat Production Emulation System (MPES) using technologies of system engineering theory, software engineering theory, computer and animation and image processing. The system consists of cooperative models, database and interface etc. Next its components will be elaborated. Using programming language Visual C++ and Visual Basic 6.0 to design system interface, MPES was developed on the operation system of Windows 2000 server. Database was built in Access 2000, and forms and graphs output was carried out by Teechart control unit. The models integrated according to COM standard by programming language Visual C++ are main content of MPES. In addition, databases, variety parameter test module and weather creation module programmed by Visual C++ are included. Basic parameters database saves variety information, soil data and agronomic management. Weather data day by day are kept in weather database. The simulation and predicting results of models were transported into result database. Interface functions implement the data transfer between models and databases.

2.1 Databases

Basic parameter database consists of information about location, fertilizer type, fertilizer management, irrigation management, cultivation variety, phenology data, soil texture and soil parameter, among which phenology data, as actual experiment data, is used to determine the genetic characteristic parameters for certain variety; soil parameters contain former crop remains information, water content before sowing, and organic matter percent, volume weight, $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$ and PH of every soil layer. The datum of daily highest temperature, lowest temperature, rain and solar radiation or sunlight time input by user are saved in weather database. The qualitatively knowledge about wheat cultivation that can not be analyzed quantitatively through models are expressed with production rule and concluded into knowledge base, which solves the practical problems by means of reasoning machine according to users' input and aim. Results database stores the simulation results from cooperative models and decision layer, and the tables are set on the basis of the output menus.

2.2 Cooperative modes

Applying system engineering, computer technology and model method, and based on the past modeling experiences, agronomic knowledge and experimental data, deep analysis on wheat growth and development discipline, we quantified wheat growth and its effective factors to several

models which realized valid cooperation. The following gives details of the main cooperative models and their functions, respectively.

Wheat growth model computes LAI, Light Interception, photosynthesis, and dry matter production and distribution in wheat, and calculates N uptake and distribution. Wheat development is divided into 8 stages in wheat development model: from sowing to germination, from germination to seeding emergence, from seeding emergence to juvenile stage, from juvenile stage to jointing stage, from jointing stage to silking stage, from silking stage to beginning of grain filling, from beginning of grain filling to physiological maturity. Temperature, water, photoperiod and genetic parameter restrict the replacement of development stages. Genetic parameter can be input by user or decided automatically by parameter determination program in system. Water balance model is built to simulate water leakage, runoff, soil evaporation, plant transpiration and root water absorption in each soil layer according to water movement rules, soil water status and wheat absorption characteristic adopting Priestly-Taylor equation and SCS Curve Number Method. N balance model mainly simulates N mineralization and fixation of organic matter in soil, N losses and uptake by crop. N deficit index calculated by the model affects directly daily accumulated value of wheat dry matter and LAI. This model considers the amount of nitrate leached out of wheat root zone (here define it as 2 meters) with water movement, and evaluated possible effects of the leached nitrate on groundwater. The effects on main wheat quality (protein, starch and fat) of variety trait, weather, cultivation management and nutrition are analyzed by grain quality model which deducted the algorithm with Logistic equation by drawing up the relation between quality and impact factors such as density, days after grain-filling, water and nutrition. In order to observe wheat growth and yield formation directly, 3D visualization model was developed on the basis of agronomic shape knowledge, image and 3D animation technology, and the simulation results.

2.3 System interface



Fig. 1 3D visualization for wheat growth

User contacts system or models by friendly and beautiful system interface (Fig. 1), which includes data input and results showed by form, graph for the daily data of more than 40 indexes and 3D visualization, and is easy to be operated and understood. The system reduces the demanding parameters that are not easy to get for user. 3D visualization show simulates the shape changes of seed, root, stem, leaf, spike and female flowers from sowing to maturity, and the corresponding content for soil water, NO₃-N and NH₄-N are displayed on the right screen simultaneously. 3D visualization for wheat growth is shown in Fig. 2.

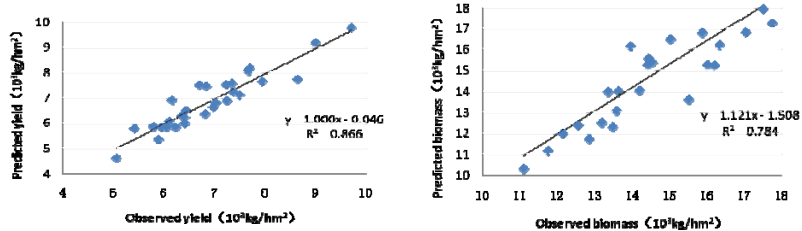


Fig. 2 Comparison of observed yield and biomass vs. predicted data

2.4 System functions

Digital wheat production including yield and yield components prediction, quality formation forecast, water and nitrogen dynamics, N and water taken up and utilization by the crop, and N loss can be simulated with WPES using various varieties under different location and soil fertility levels with one day as time step. The system expresses the simulation results directly with form and figure. It gives anticipative target yield and quality, variety choose,

sowing date and density determination, fertilizer and water management according to user's requirement and biological environment of decision location. Based on cooperative models, system analyzes wheat variety, water and nutrition status, weather resource and offers assistant decision-making, such as the suggestions on optimal variety, sowing date and density, the amount and time of irrigation and fertilizer. In the meantime, combining with simulation results from cooperative models related to wheat growth and configuration, 3D visualization simulates wheat morphological development vividly using animation and image processing technologies. System functions are as following: predicting wheat yield and development, estimating water and nitrogen utilization and nitrogen loss, recommending water and nitrogen management scheme, evaluating cost-benefit, offering assistant decision-making and showing 3D wheat growth.

3. APPLICATION EXAMPLE OF WPES IN HEBEI PROVINCE

WPES was calibrated and validated with data gotten from Wuqiao experimental station in Hebei province which existed in Huang-huai-hai plain, China. Cooperative models of WPES consist of 5 variety genetic characteristic parameters, i. e. relative vernalization sensitivity, relative photoperiod sensitivity, relative value of conversion factor for grain number per unit stem weight relative duration of grain filling phase, relative value of maximum possible daily growth rate of a kernel, relative value for potential dry weight of a single stem and ear at anthesis. Before the system can be used, user should validate model according to weather data and observed value to determine variety characteristic parameters. Weather data include daily maximum temperature, minimum temperature, total radiation and rain.

There are experimentation data for four seasons in whole. Detailed design materials and methods were described by references (Zhou Shunli, et al, 2002; Wang Qixian, 2001; Li Jianmin et al, 2000). This paper just makes use of partial data to prove model system mentioned above. In 1994-1995 and 1995-1996 seasons four irrigation treatments including different irrigation frequency and equal irrigation quota were set up with wheat variety 95021, and one treatment was adopted to validate model for every season and the rest were used to model test. In 1997-1998 and 2002-2003 seasons effect of four nitrogen gradients (0, 90, 180, 270 kgN ha⁻¹) on four varieties (95021, Heng 4041, 6029 and Shannong 45) was tested. We validated model using one treatment for every variety and season to determine genetic parameters, and used the remainder to test model or system.

After running WPES the simulated yield and above biomass for four seasons were achieved. Fig. 3 indicates observed yield and biomass relate predicted data significantly at $\alpha=0.01$. The relative coefficient is 0.931 for predicted and simulated yield, 0.832 for predicted and simulated biomass. RMSEs that can reflect simulation error of yield and biomass are 406.4kg ha⁻¹ and 1340.4 kg ha⁻¹ respectively. The ratio of RMSE to average observed data (i. e. average RMSE), which expresses deviation more accurately are 5.89% and 8.94% respectively. Although the deviation for predicting yield and biomass less than 10%, it's obvious the system forecasts yield better than biomass. The possible reason is system simulates biomass including dead tillers and dry leaves which can't be contained in observed biomass. Meanwhile complicated factors from the randomness of field production affect wheat growth, but many of them are not possible to be considered by crop model. With the further improvement holding more environment factors to perfect model will enhance prediction ability of crop model.

4. CONCLUSION

Taking wheat as study object, analyzing the relationship among crop, environment and management practice, applying system engineering theory, dynamic simulation and visualization technologies, wheat simulation model based on growth development was constructed. Then authors designed WPES and realized wheat 3D visualization with component object programming (COM) standard. The aim of this study is to forecast wheat production system accurately, manage and monitor wheat growth scientifically and timely.

WPES includes wheat growth model, development model, water and nitrogen balance model, grain quality model, economic analysis model and 3D visualization model as well as databases and knowledge base. Using experimental data for four seasons of same location in Hebei province to calibrate and validate the system proved its good prediction performance with less than 10% simulation deviation for yield and biomass. And the yield had more accuracy than biomass. Of course it is far from enough for model validation data with one location. Though the parameters were determined and corrected with field data from Hebei, Shandong and Beijing etc. which plant wheat as a main grain crop, we will improve and perfect WPES according to the data from demonstration stations which keep frequent communication and cooperation with us. After the system achieves high accuracy of predicting yield and biomass, the water and nitrogen balance will be validated.

Confined to existing agricultural knowledge, WPES considers mainly such eco-physiology processes as carbon balance, water and nitrogen balance, and their mutual action. Since agricultural system is a dynamic and complicated multi-factor system, model system must include more impact factors to the full in order to approach actual production system such as the effect of phosphate and potassa on wheat growth and the coupling between fertilizers, harmfulness of plant diseases and insect pests and the pesticide effect. All these need agricultural researchers and software designers to work hard together.

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FAST MEASUREMENT OF SOLUBLE SOLID CONTENT IN MANGO BASED ON VISIBLE AND INFRARED SPECTROSCOPY TECHNIQUE

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Abstract: Mango is a kind of popular tropical fruit, and the soluble solid content is an important in this study visible and short-wave near-infrared spectroscopy (VIS/SWNIR) technique was applied. For sake of investigating the feasibility of using VIS/SWNIR spectroscopy to measure the soluble solid content in mango, and validating the performance of selected sensitive bands, for the calibration set was formed by 135 mango samples, while the remaining 45 mango samples for the prediction set. The combination of partial least squares and backpropagation artificial neural networks (PLS-BP) was used to calculate the prediction model based on raw spectrum data. Based on PLS-BP, the determination coefficient for prediction (R_p) was 0.757 and root mean square error for prediction (RMSEP) was 0.865. It is concluded that infrared spectroscopy technique can quantitative the soluble solid content in mango, and the process is simple and easy to operate. Compared with the Partial least squares (PLS) result, the performance of PLS-BP is better.

Key words: Mango, soluble solid content, PLS-BP, near-infrared spectroscopy

1. INTRODUCTION

Mango is a kind of popular tropical fruit. It is rich in organic acid and carotene, and it is benefit to people's health. Nowadays, a good tasting and high nutrition is the critical factors to commercial benefits. As a result, it is

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urgent to find a better way to determine the quality to ensure farmers' interests. However, most techniques available for soluble solid content analysis are time consuming, destructive and costly, and require professional operations. Therefore, it is much-needed for the development of a reliable, non-destructive method.

Recently, the visible and short-wave near-infrared spectroscopy (VIS/SWNIR) technique (wavelengths range from 400 to 1075 nm in this study), has received interest because of its non-destructive analyses for biological and biomedical materials. Because of its high transmittance and fast responses, it is suitable as an excellent detector. In the VIS/SWNIR region, there are several advantages such as the signal exploitation is reliable, the measurement time is low (J. B. Reeves et al., 1994) and the effective of intense water bands in NIR region can be diminished (S. Sasic et al., 2001).

For the recently quantitative analysis, Saona et al. determined individual sugars in fruit juices using FT-NIR and multivariate techniques (Saona et al., 2001), Liu et al. used visible and near infrared spectroscopy to assess soluble solids content and pH of rice wine. (Liu, F. et al., 2007)

Since mango is rich in organic acid and carotene, and the organic acid and carotene can influence the soluble solid content (Shao, Y. N. et al., 2007), which leads to highly overlapped peaks and regardless of bandwidth in infrared spectroscopy. At the same time there is much noise and other unrelated information arises from overtones and combinations of such vibrations, rendering them much more difficult to interpret. For sake of finding the relevant quantitative information, especially the nonlinear one, it is necessary to use the suitable and effective chemometrics methods. Propagation artificial neural networks in this study was used.

The aim of this study was to explore the feasibility of using VIS/SWNIR spectroscopy to discriminate different brands of mango. A nonlinear mathematical method for rapid, nondestructive identification of lubricating brands was developed by BP-ANNs. In order to validate the performance of selected effective wavelengths of mango, loading weights in Partial Least Squares (PLS) were analyzed.

2. MATERIALS AND METHODS

2.1 Sample preparation

180 mango samples were purchased in local market. They were stored in the lab for 24 hours with a constant temperature of 25 ± 1 °C to equalize the temperature. 135 mango samples were randomly selected for the calibration set, while the remaining 45 samples for the prediction set.

2.2 Spectra measurement

For each sample, reflectance spectra were scanned by a handheld FieldSpec Pro FR (325–1075 nm)/A110070, Trademarks of Analytical Spectral Devices, Inc. (Analytical Spectral Devices, Boulder, USA) for three times each. The light source consists of a Lowell pro-lam interior light source assemble/128930 with Lowell pro-lam 14.5V Bulb/128690 tungsten halogen bulb that could be used both in visible and near infrared region. The field-of-view (FOV) of the spectroradiometer is 10°. The spectroradiometer was placed at a height of approximately 250 mm and 45° angle away from the center of sample. The light source was placed at a height of approximately 150 mm 45° angle away from the sample. The spectrum of each sample was the average of 30 successive scans with 1.5 nm intervals. Three spectra were collected for each sample and the average spectrum of these two measurements was used in the later analysis. All spectral data were stored in a computer and processed using the RS3 software for Windows (Analytical Spectral Devices, Boulder, USA) designed with a Graphical User Interface.

2.3 Spectral data pretreatment

The reflectance spectra were firstly transformed into ASCII format by using the ASD ViewSpecPro software (Analytical Spectral Devices, Boulder, USA). Then three spectra for each sample were averaged into one spectrum and transformed by $\log(1/T)$ into absorbance spectrum. The pretreatments were implemented by “The Unscrambler V 9.7” (CAMO PROCESS AS, OSLO, Norway). Because of the high noise at the beginning of the spectrum, 421-1075 nm was used in this study. After some trial computations, the optimal smoothing way of moving average with 3 segments was applied to decrease the noise. Standard normal variate (SNV) was applied for light scatter correction and reducing the changes of light path length, but it was showed the raw spectrum data's result was closed to the pretreated data. In order to reduce the processing time, in this study the raw spectrum data was chosen.

2.4 Backpropagation artificial neural networks

Backpropagation artificial neural networks have one or more hidden layers nodes besides input node and output node, and there is no coupling in the same hidden layer (M. R. Widyanto, et al.2005). The input signals can be passed through hidden layer node from the input node to the output node. The output of on layer becomes the input to the following layer. The transfer function of node takes the form:

$$f(x)=1/(1+e^{-Q/x}) \quad (1)$$

In the function, Q is the parameter of function, in this study Sigmoid was used.

Propagation artificial neural networks is a kind of multi-storey network used Widrow-Hoff learning algorithm and nonlinear differentiable functions. Gradient descent algorithm is used in a typical BP network, which is Widrow-Hoff algorithm requirements (Aleksandra Vuckovic, et al.2002). Backpropagation is referred to this kind of algorithm. This recursive algorithm can be rewritten as:

$$xk + 1 = xk - ak \bullet gk \quad (2)$$

Here xk is the current weight and bias vector, gk is the current gradient, ak is the learning rate.

2.5 Reference method for SSC

The reference value of SSC was measured by an Abbebenchtop refractometer (Model: WAY-2S, Shanghai Precision & Scientific Instrument Co. Ltd., Shanghai, China). The refractive index accuracy is ± 0.0002 and the Brix (%) range is 0-95% with temperature correction.

3. RESULT AND DISCUSSION

3.1 Spectral Features of mango

Fig 1. shows the transmission's spectrum of mango. Because there were a lot of noises between 350 nm and 400 nm ,in this study 400 nm-1075 nm was used.

As seen from the picture, in visible spectrum, the absorption in 400 ~ 550 nm is greater than 550 ~ 770 nm's absorption, it is caused by the mango's yellow skin pigments and carotenoids (Manuela Zude, et al.2006). And in near infrared spectrum ,there is a peak between 950 nm and 1075 nm, it may be caused by hydroxy and hydrocarbyl. The skin's colour and organic compounds could influence the soluble solid content. So it could be seen that the VIS/NIR technique maybe a way to determine the soluble solid content.

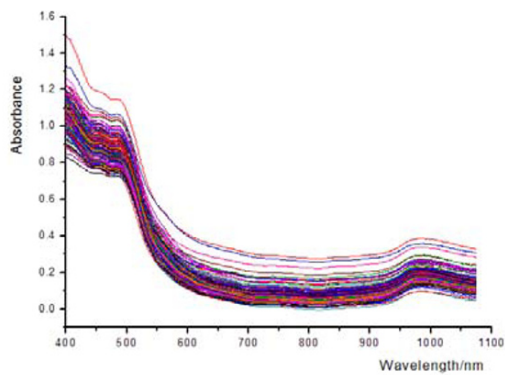


Figure 1. Whole Absorbance spectra of mango

3.2 The soluble solid content of mango

From the Fig. 2. and Table 1. it can find that the reference value of SSC for mango had a high variation coefficient. It may affect the modeling results, but also benefit to find more outstanding model.

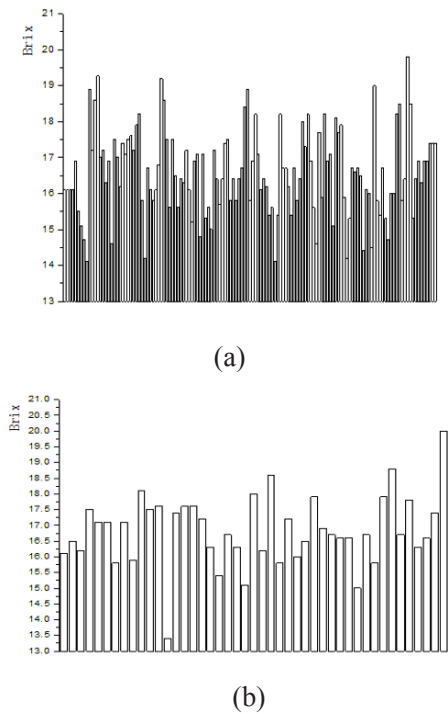


Figure 2. The SSC of calibration set (a) and prediction set(b)

Table 1. The SSC value of mango

Set	Calibration	Prediction
Sample number	135	45
max	20.00	20.00
min	14.10	14.20
mean	16.58	16.83
Standard deviation	1.96	1.11
Coefficient of variation	11.80	6.62

3.3 Spectra analysis of SSC on VIS/SWNIR

Two models were developed using same sample sets. Based on the model developed, the PLS model was applied to the all samples. Two chemometric methods, namely PLS and BP-ANNs were applied. All samples were processed by PLS before regression to get the feature input subset (LVs) for BP models.

The results of the calibration and prediction for these two separate models are shown in Table 2. BP-ANNs models did a better job with higher determination coefficient R_c^2 and R_p^2 and lower Root mean square error for calibration (RMSEC) and Root mean square error for prediction (RMSEP) than PLS. RSD% and PRESS also performed better in BP models. Thus , very good determination performance for SSC in mango can be achieved by VIS/WSNIR spectra. There is relationship between SSC and VIS/SWNIR spectra.

Table 2.Results for SSC of mango from VIS/SWNIR Spectra

Set	Method	PCs	R_c or R_p	RMSEC or RMSEP	PRESS
Calibration	PLS	17	0.902	0.546	34.890
	PLS-BP	/	1.000	0.021	0.052
Prediction	PLS	17	0.660	0.964	33.871
	PLS-BP	/	0.757	0.865	32.645

4. CONCLUSION

The measurement of SSC of mango could be successfully performed through visible and short-wave near-infrared spectroscopy combined with chemometric methods of PLS and BP-ANNs. The raw spectrum was used. The precision and accuracy was achieved by PLS and LS-SVM models with the R_p and RMSEP were 0.660, and 0.964 for PLS, 0.757 and 0.865 for LS-SVM, respectively. RSD% and PRESS also performed better in BP models. The results indicted that visible and short-wave NIR spectroscopy had the capability to determine the carbohydrate content in milk powder. Further

interpretation of the input data selection, parameter optimization and results explanation would be needed in order to improve the calibration generalization and stability.

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USE OF NIR SPECTROSCOPY AND LS-SVM MODEL FOR THE DISCRIMINATION OF VARIETIES OF SOIL

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Abstract: Near-infrared spectroscopy (NIR) combined with chemometrics method was employed in this paper. The objectives were to investigate the feasibility of using VIS/SWNIR spectroscopy to discriminate soil of different kinds, and to validate the performance of selected sensitive bands. Spectra in the NIR regions (4003.563-12496.67 cm^{-1}) were collected from 380 samples and the data was expressed as absorbance, the logarithm of the reciprocal of reflectance ($\log 1/R$). 240 samples were randomly collected as modeling, and the others were used to check the model's performance. Principal components analysis (PCA) tested the clustering of these four kinds of soil, which made a qualitative analysis for the discrimination, but for the sake of speeding up the calculating time, the mathematics analysis of support vector machine classification and 10-folds cross-validation were used to model, and Based on SVM, the recognition ratio of 98% (0.2 as threshold value) was obtained. Compared with the PLS result of 79% (0.2 as threshold value), SVM classification is apparently more effective. At the same time, the sensitive bands of soil varieties were calculated, in which we found the 801-972 nm can predict well with the result of 90% from LS-SVM. The prediction results of 99% indicated that the NIR can mainly represent the characteristics of soil of different kind based on SVM model.

Keywords: NIR; chemometrics; soil; PCA; SVM

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1. INTRODUCTION

The prospect of meeting the world's food demand for an additional people in future is a formidable challenge, but it is also an obligatory for our studies. Higher technology is needed, so precision agriculture is one agronomic means of meeting this challenge. The concept of precision agriculture entails the use of some high-tech equipment of assessing field conditions and applying chemicals and fertilizers (Dan Ess et al.1997). Therefore, finding a faster and more efficient technology to discriminate the varieties of soil is a key point in precision farming, whereas the ways to differentiate the soil can not meet the demand of precision farming, which are lower-tech depend on the farmer self, which are too complex ,time-consuming, laborious and may indirect such as measuring soil pH in the field with an ISFET (Viscarra Rossel R A et al.2004) and measuring clay content using EMI instruments (Sudduth K A et al.2001). So it is necessitous to find a faster and cheaper technology to make the breakthrough.

Recently, the visible and short-wave near-infrared spectroscopy (VIS/SWNIR) technique ranging from 400 to 1075 nm, has been widely applied because of its non-destructive feature for biological and biomedical materials, such as discrimination of varieties of apple (He, Y. et al.2006) and other fruits , geographic classification of wine (Liu, L. et al.2006). it is suitable as an excellent detector .. In the VIS/SWNIR region, there are several advantages such as the signal exploitation is reliable, the measurement time is low and the effective of intense water bands in NIR region can be diminished (J. B. Reeves et al.1994). with reliable signal transformation, low time-consuming, and sensitive spectral response of water.

The presence of soil constituents such as iron oxides, organic matter (OM) and water content lead to overlapped peaks spectroscopy. So it show the feasible of NIR technology used in discriminate soil varieties. In addition, there is much noise and other unrelated information arising from overtones and combinations of such vibrations, rendering them much more difficult to interpret. For sake of finding the relevant quantitative information, especially the nonlinear one , it is necessary to use the suitable and effective chemometrics methods. Least-squares support vector machine In this study ,LS-SVM and PCA is used, Least-squares support vector machine (LS-SVM) is an optimized algorithm based on standard SVM by Suykens et al. (J. B. Reeves, et al.1994).

The aim of this study was to explore the feasibility of using NIR spectroscopy to discriminate different varieties of soil. A nonlinear mathematical method for rapid, nondestructive identification of soil was developed by LS-SVM. In order to validate the performance of LS-SVM, PLS is used to be a comparison analysis.

2. MATERIALS AND METHODS

2.1 Sample preparation

The soils were obtained from different region which belong different varieties (One of the Haining soil belongs to coastal saline soil, and the other Haining soil and Cixi soil belongs to paddy soil Quzhou soil belongs to red soil.) The soil samples were prepared in same capacity. for each ,and the sample number for each variety was 100(totally 400 samples).They were stored in the lab with a constant temperature of 25 ± 1 °C to equalize the temperature. 300 samples were randomly selected for the calibration set, while the remaining 100 samples for the prediction set.

2.2 Spectra measurement

For each sample, reflectance spectra were scanned by a handheld FieldSpec Pro FR (325–1075 nm)/A110070, Trademarks of Analytical Spectral Devices, Inc. (Analytical Spectral Devices, Boulder, USA) for three times each. The light source consists of a Lowell pro-lam interior light source assemble/128930 with Lowell pro-lam 14.5V Bulb/128690 tungsten halogen bulb that could be used both in visible and near infrared region. The field-of-view (FOV) of the spectroradiometer is 10°. The spectroradiometer was placed at a height of approximately 250 mm and 45° angle away from the center of sample. The light source was placed at a height of approximately 150 mm 45° angle away from the sample. The spectrum of each sample was the average of 30 successive scans with 1.5 nm intervals. Three spectra were collected for each sample and the average spectrum of these two measurements was used in the later analysis. All spectral data were stored in a computer and processed using the RS3 software for Windows (Analytical Spectral Devices, Boulder, USA) designed with a Graphical User Interface.

2.3 Spectral data pretreatment

The reflectance spectra were firstly transformed into ASCII format by using the ASD ViewSpecPro software (Analytical Spectral Devices, Boulder, USA). Then three spectra for each sample were averaged into one spectrum and transformed by $\log(1/T)$ into absorbance spectrum. The pretreatments were implemented by “The Unscrambler V 9.7” (CAMO PROCESS AS, OSLO, Norway). Because of the high noise at the beginning of the spectrum, 421-1075 nm was used in this study. After some trial computations, the

optimal smoothing way of moving average with 3 segments was applied to decrease the noise. Standard normal variate (SNV) was applied for light scatter correction and reducing the changes of light path length.

2.4 Least squares support vector machines (LS-SVM)

Support Vector Machines (SVM) is a powerful methodology for solving problems in nonlinear classification, function estimation and density estimation which has also led to many other recent developments in kernel based learning methods in general (Cristianini N. et al.2000), which have been introduced within the context of statistical learning theory and structural risk minimization. like SVM, In the LS-SVM algorithm, a non-linear mapping function $\phi(\cdot)$ is obtained by constructing the regression model while the input data is mapped to a higher dimensional feature space. When the least-squares support vector is used as a soft testing tool, a new optimization problem is formulated in the case of SRM. And then, Lagrange function is adopted to solve this optimization problem. Based on Mercer's theory, there is an equation between kernel function $K(x_i, x_j)$ and mapping function $\phi(\cdot)$:

$$\begin{aligned} \phi(x_k)^T \phi(x_l) &= K(x_k, x_l) \\ k, l &= 1, \dots, N \end{aligned} \quad (1)$$

The kernel function must meet Mercer theorem. The common examples of kernel function contain linear, polynomial, radial basis function (RBF) kernel and multi-layer perceptron (MLP). In this study, RBF kernel was selected. The formula is:

$$K(x_k, x_l) = \exp\left(-\frac{\|x_k - x_l\|^2}{\sigma^2}\right) \quad (2)$$

Finally, the LS-SVM regression model can be obtained as:

$$y(x) = \sum_{k=1}^N \alpha_k K(x, x_k) + b \quad (3)$$

A good LS-SVM classification model with high prediction accuracy and stability is built based on proper parameter setting. Grid-search technique is applied to find out the optimal parameter values which include regularization parameter γ and the RBF kernel function parameter σ^2 (σ^2 is the bandwidth in the common case of the RBF kernel). γ determines the trade-off between SRM and ERM, and is important to improve the generalization performance of LS-SVM model. σ^2 controls the value of function classification error, and influences the number of initial eigenvalues and eigenvectors directly. Moreover, σ^2 reflects the sensitivity of LS-SVM

model to the noises from input variables. All the aforementioned calculations were performed using MATLAB 2006b (The Math Works, Natick, USA).

3. RESULT AND DISCUSION

3.1 Spectral features of soil

Fig. 1 shows the whole transmission's spectra of four kinds of soil It can be finded that there are same trend in the spectra, and hav a little different in some peaks . The baseline changes are the main differences from one spectrum to another while they are unavoidable in spectra, and different types of pretreatment have been applied to the spectra to eliminate them (R. Tsenkova, et al.1999; Y.J. Chen, et a1999). One of the pretreatment methods often used is standard normal variate (SNV). SNV was applied for light scatter correction and reducing the changes of light path length. In the spectra, the baseline changes are induced maybe by the light scattering due to the size of powder granule. Hence, we have applied SNV to the spectra. But it is still difficult to discriminate the soil .Therefore, further treatments would be needed and then the latent features of the spectra could be applied.

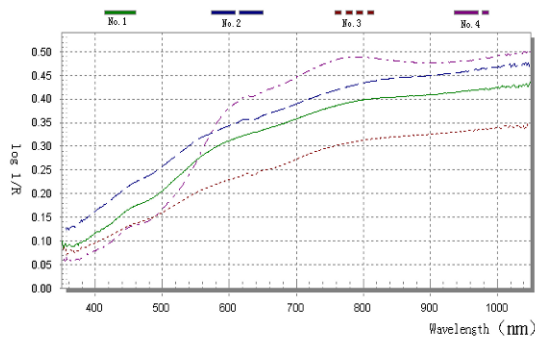


Fig. 1. Whole Absorbance spectra of soil

3.2 Principal components analysis (PCA) Clustering

PCA is a method for the re-expressing multivariate data. It allows the researcher to reorient the data so that the first few dimensions account for as much of the available information as possible. The principla components solution has the property that each component is uncorrelated with all others, which has the advantage of eliminating multicollinearity. The principal

components (PCs) plot obtained using the first primary PCs can be used for the partern recognition.

Fig. 2(a) shows the accumulative reliabilities of the PCs. It indicated that the accumulative reliabilities of the first tow PCs could explain up to 99.9% of the total variance. The third PC only interpreted an additional information which is less than 0.1% and it can not contribute so much as the aforementioned PCs. So the first three PCs were considered as the inputs of the cluster plot. Fig.2(b) shows each varieties was clustered well.

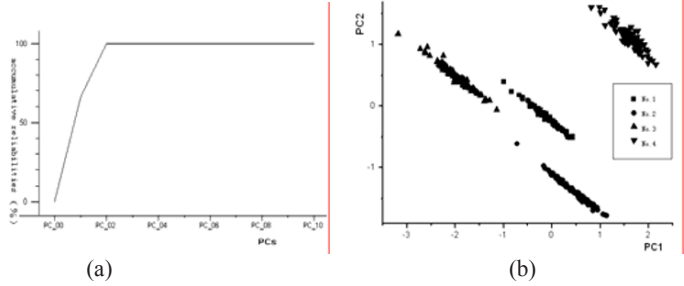


Figure 2.PC accumulative reliabilities of soil(a) and Cluster plot with PC1xPC2 of four varieties of soil(b)

3.3 LS-SVM Classification Model

With the encoding and decoding of the output varieties , LS-SVM classification model can use to slove multi-class problems, The coding is defined by a codebook. The codebook is represented by a matrix where the columns represent all different classes and the rows indicate the results of the binary classifiers. The four brands with original labels [1 2 3 4] were encoded in the following codebook (using Minimum Output Coding) (Table 1):

Table 1.Multiple binary classifiers for output sets of LS-SVM for three Brands

Brand No.	1	2	3	4
Binary Classifiers	-1	-1	1	1
	-1	1	-1	1

Finally, the classified results of LS-SVM are decoded again to its original form. Two models were developed using different sample set consisting of 600 spectra each. Based on the model developed, the LS-SVM model was applied to predict the 45 remaining samples after similar mathematical pretreatment to the calibration ones. LS-SVM was performed with RBF kernel. In the LS-SVM model, the determination of parameters γ and σ^2 is important. In this study, these parameters were optimized with values of γ in the range of 2-1-210 and σ^2 in the range of 2-215 with adequate increments by grid-search technique of “leaveoneout_lassvm” Validation. These ranges were chosen from previous studies where the magnitude of parameters to be

optimized was established. For each combination of γ and σ_2 parameters. Because there are two levels in each row of binary classifiers (Table 2) and LS-SVM classification model can only classify two varieties, the LS-SVM classification model needs to process on these two rows (dimes) separately. The optimal pair of (γ, σ_2) and prediction results for model is shown in Table 3 and the results show a satisfying prediction precision.

Table 3. Prediction results for these two separate models

γ_1	γ_2	σ_1^2	σ_2^2	Variety	Prediction (n=25×4)
					Recognition ratio
2.3608	0.9477	5.6394	6.2498	1	100%
				2	96%
				3	100%
				4	100%
				All	99%

3.4 Selections of sensitive bands

In order to obtain the sensitive wavebands for further designing of optical instruments, a calibration model based on the 400 samples of calibration set was calculated both by PLS analysis. The optimal number of LVs in PLS analysis was determined as four by full cross-validation. These wavelengths with small absolute x-loading values were less important than those with large ones. From loading weights of each LV, there are some sensitive bands chose: 525 nm, 634 nm, 801-972 nm in regression coefficients Fig. 3(a), Also, these sensitive bands can also been found in LV1-LV4 Fig. 3(b). But we still find that the peak at 525 nm and 634 nm appeared not constantly in each LV's loading weight, so more work need to do. In order to know the sensitive bands, the band from 801-972 nm (Fig. 4) were used to analysis by PLS again, in which we find the importance of them are very close, Thus, we chose these wavelengths as the input of LS-SVM, Each wavelengths predict the 100 remaining samples. when it goes to LS-SVM, the results of 801-972 nm (totally 164 bands) are between 0.83 to 0.93. still very close. But the results of 525 nm and 634 nm is 25% and 20%, which can not meet to the demand.

So the 801-972 nm were used to be the sensitive bands of soil's varieties, and the result of it from LS-SVM is 90%.

The prediction results indicated that the selected wavelengths of 801-972 by loading weights and regression coefficients and the result of LS-SVM analysis can reflect the main characteristics of soil of different varieties. The sensitive wavelengths would be useful for the development of portable instrument or online applications to discriminate the varieties of soil.

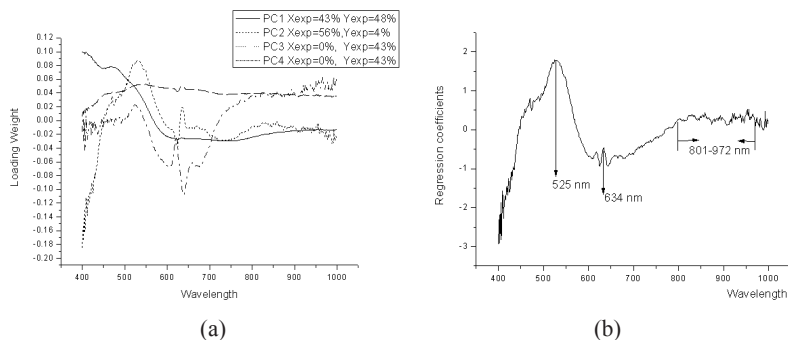


Figure 3. Regression coefficients (a) and loading weights (b) of whole spectrum

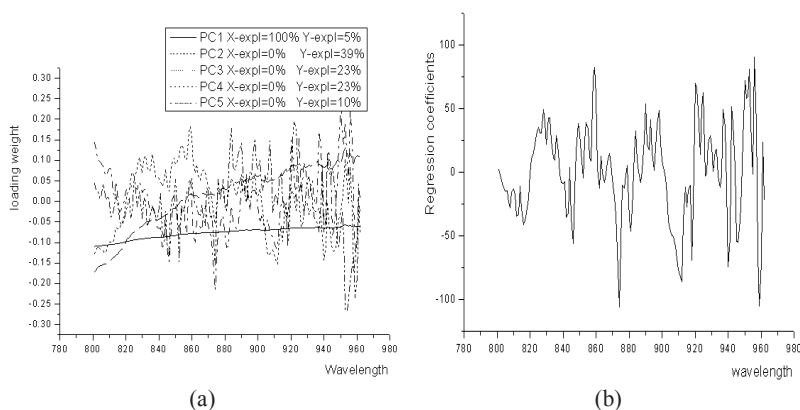


Figure 4. Regression coefficients (a) and loading weights (b) of 801-972 nm

4. CONCLUSION

NIR spectroscopy was successfully utilized for the identification of soil's varieties. An excellent recognition ratio of 100% was achieved based on LS-SVM. The results demonstrated that NIR spectroscopy has the potential ability to identify soil with different internal qualities. The sensitive bands for the discrimination would be helpful to develop portable instruments for commercial applications of adulteration detection. Therefore, more samples of different brands should be included to expand the model and improve the model generalization, specificity and accuracy.

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GIS-BASED DISASTER WARNING SYSTEM OF LOW TEMPERATURE AND SPARE SUNLIGHT IN GREENHOUSE

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Abstract: The disaster that low temperature and spare sunlight occurred in North China is a major weather hazards to the sunlight greenhouse vegetable growing. The establishment of disaster warning system of low temperature and spare sunlight for greenhouse is of great significance to the disaster mitigation and prevention. According to the climate characteristics of Hebei Province and regional distribution of greenhouse, under the support of GIS and computer technology, using C/S structure, the early warning system was developed with multi- functions such as data acquisition automatically, disaster early warning, documentation services generating, early warning test and so on. This paper introduced briefly about the system operating environment, structure, function, operational process, as well as disaster warning results displaying. Operational applications showed that GIS-based system can describe the occurrence, distribution and intensity of disasters objectively, also provide a scientific basis for disaster prevention and mitigation.

Keywords: Sunlight Greenhouse, Low Temperature and Spare Sunlight, Disaster Early Warning, Computer-system, GIS

Hebei Province is located in the North China Plain, where upper air is controlled by northwest air current generally in autumn and winter and the solar radiation resources is quite rich, thus it is able to provide the natural energy for the sunlight greenhouse vegetables production(Su Jianqin et al., 1996). The sunlight greenhouse area has already been amounted to 200,000

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hectares until the year of 2006, the second ranked in the whole nation, since 1996 the first sunlight greenhouse was established in Hebei Province. Up to now, its productions of vegetables for major cities, such as Beijing and Tianjin, have had a solid market share. But as a result of both geographical location and climatic characteristics, it is easy to appear the overcast (snow or fog) weather during the sunlight greenhouse vegetables growing period in the central and southern regions of Hebei Province, which causes the occurrence of disasters that low temperature and spare sunlight, and consequently brings a great loss to the vegetables productions ([Zhao Yuguang et al., 2004](#); [Huazhong Agricultural University, 1986](#); [Wei Ruijiang, 2003](#)).

It is not only of urgent necessary for the modern agricultural production to reinforce the disaster mitigation and prevention of low temperature and spare sunlight in greenhouse, but also an important aspect of meteorological service for agriculture production. The rapid development of the modern information technology, especially geographical information system (GIS) technology, makes it quite possible that the real-time dynamic monitoring and early warning for the occurrence region, intensity and scope of disasters that caused by low temperature and spare sunlight.

Based on the disaster indexes of low temperature and spare sunlight and real-time meteorological data, as well as future numerical weather forecast products, early warnings about the disaster would be carried on, and also provided the service information for the disaster prevention and mitigation, which is capable to describe the occurrence intensity and regional distribution of disasters.

1. OPERATING ENVIRONMENT

Hardware environment: CPU is Pentium IV or above, memory is 512MB or more, hard disk space 80 G or more.

Software environment: OS is Windows2000 or above.

2. SYSTEM STRUCTURE

System software was developed by C⁺⁺ language, and adopting the frame of C/S, including server and client of two parts. The server is consisted of two parts, one is database which using SQL 2000 Enterprise Edition to collect and store various data that systems required for the operation; the other is data synchronization calculation module, which works at the fixed time every day, collects the necessary data automatically, and stores the data into the database, all fully performed automatically without user intervention.

The client provides users with an interactive interface, by which the operations would be carried on, such as information inquiry, disaster early warning, early warning prove, services document generation and so on. The system structure was illustrated in Fig. 1.

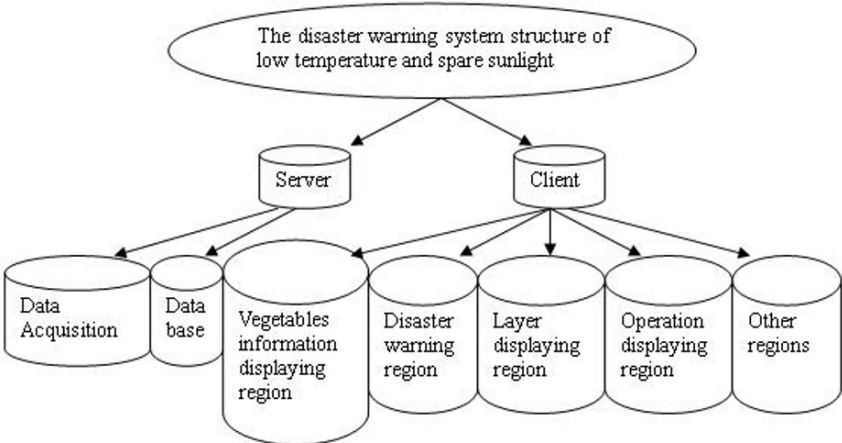


Fig.1. The structure of system for low temperature and spare sunlight

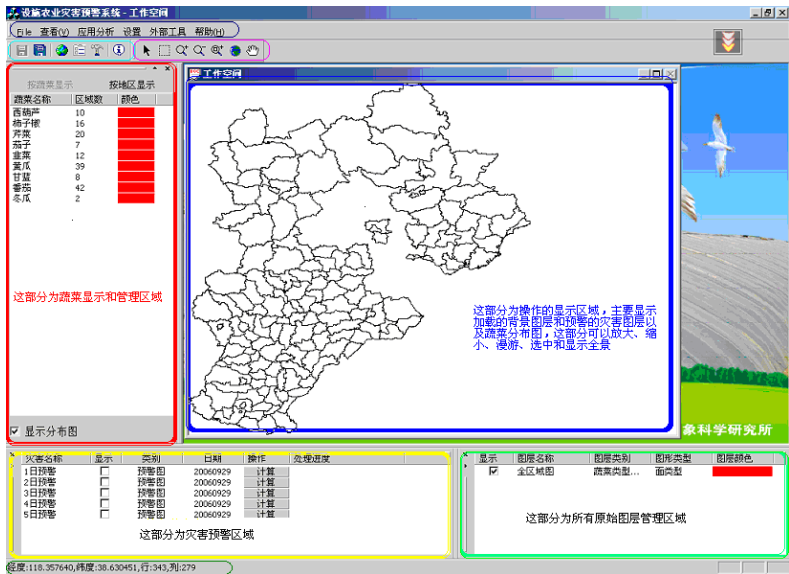


Fig.2. The main client interface

Fig.2 shows the main client interface, including four major parts and several others. The major are as follows: vegetables information displaying, with red marked on the main client interface, shows all types of vegetables

existed in the system and their spatial distribution; disaster warning with yellow marked, rolling early warning day by day in future 5 days would be implemented; layer displaying with blue marked is to load the background layer and the results of early warning as well as distribution map of vegetables; and operation displaying with green marked shows the names, types and colors of all layers existed in system. Others include menu, main toolbar, ordered toolbar and status bar.

3. SYSTEM FUNCTION

The block diagram of system function is given in Fig. 3. Seven major functions of the system are as the following:

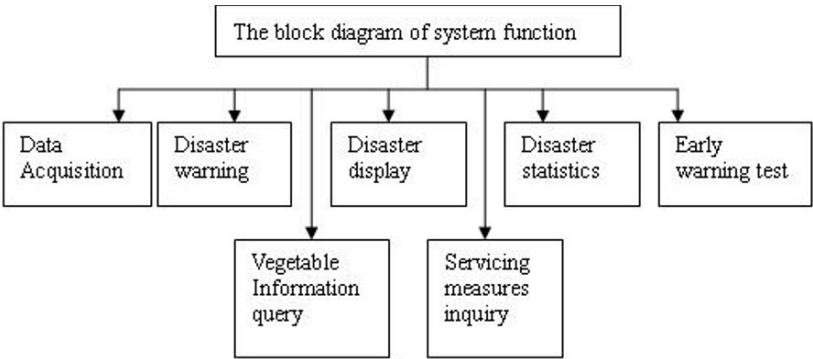


Fig.3: The block diagram of system function

(1)Data Acquisition: This module which is installed on the server would be activated at the fixed time every day automatically in order to acquire daily meteorological data on the LAN (local area network) and to store them in the database. The data include daily sunshine hours, minimum and maximum temperature observed in each station of the province as well as daily numerical weather forecast products.

(2)Vegetable Information query: This module shows vegetable types and spatial distribution of sunlight greenhouse located in all counties of the whole province. It displayed in two ways, one is display by vegetables and another is by regions. The former display shows the distributing regions of different types of vegetables, and the latter shows the types of the sunlight greenhouse vegetables in every county, indicated with the pie chart, and several kinds of the vegetables would be divided into equal parts in a pie chart.

(3)Disaster warning: It's the chief module of the system, besides to read the vegetables information in the database, the current live weather

information and the future numerical weather forecast information, its function is to identify automatically whether it to occur or not a disaster, its regions and intensity in the future five days in response to the disaster indexes of low temperature and spare sunlight for different types of vegetables. Disaster early warning is divided three classes, i.e., light, moderate and severe, generating the early warning map (including disaster intensity and disaster regions) and vegetables growth and development status as well as the "word" format document about management measures automatically too.

(4)Disaster display: It shows the background layer, result layer of disaster early warning and the map layer for vegetables distribution, with the functions of picture zooming, roaming, checking and displaying panorama features and so on.

(5)Servicing measures inquiry: We can use this module to check the different type vegetables suitable condition, the potential disaster, results of disaster and the defense management measures in two ways, which is follow as "the vegetables development stages as the sequence" and "the ten-day period as the sequence". As to them, we may increase, modify, delete arbitrarily. "The vegetables development stages as the sequence", as the name implies, takes the different development stages of vegetables as the sequence such as the seeding, planted, flower and harvested. "The ten-day period as the sequence" is implemented according to the time sequence, such as in early January, mid-January.

(6) Disaster statistics: It would count the times of disasters that low temperature and spare sunlight of different extent occurred in counties at random period. In addition, it would record the occurred time of disasters by the way the same as number of times.

(7) Early warning prove: It would take the number of times of disasters and the actual number as a comparison with the intention of testing results of early warning.

4. EARLY WARNING FLOW-CHART

First, each kind of data which system needs to be transferred, including the vegetable types of various counties (cities) in Hebei Province, the disaster indexes of low temperature and spare sunlight, the daily sunshine hours observed and daily numerical weather forecast products in the future of five days. Then computation would be carried on for the whole 142 sites of the province according to the disaster early warning indexes, to determine whether it occurs or not a disaster. Early warning output uses Hebei Province map as background and generates pictures. The system can automatically

search for the current development stage of vegetables and service measures in service measure database and put them into the WORD format documents with generating early warning results. Finally the service product would be formed through the manual edition. The early warning flow is shown in Fig. 4.

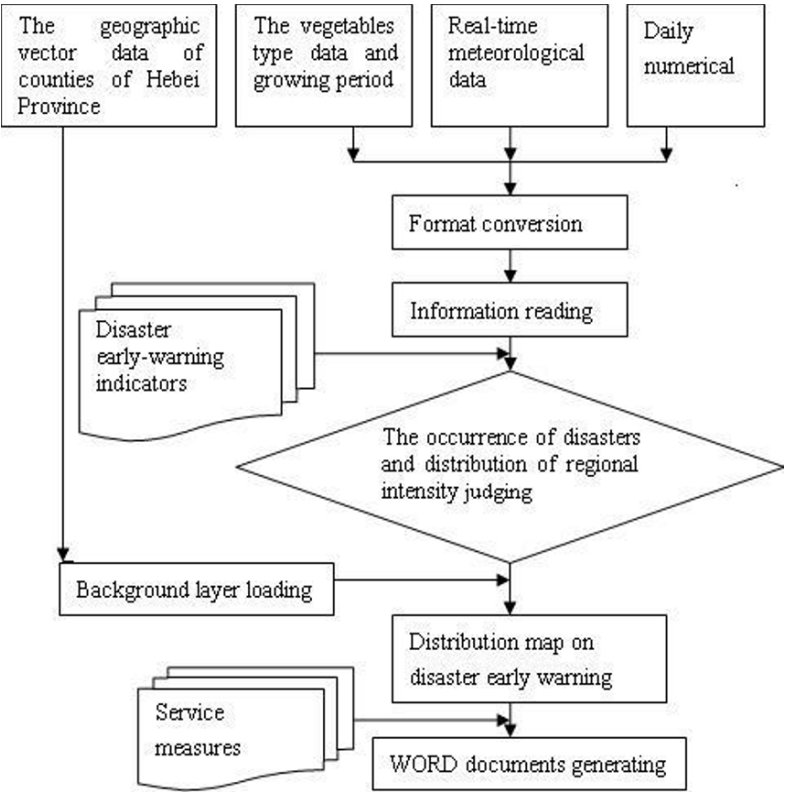


Fig.4. The flow diagram of the early warning system

5. DISASTER EARLY WARNING RESULT DISPLAY

Geographical data set comes from the national basic geographic information system center. Under the technical support of GIS, the geographic data of Hebei Province can be conversed, overlay, stitched, tailored and formed geographical background data set including 142 counties (cities) of Hebei Province. The regions out of the province boundaries are defined as 0, the regions that cities and counties within the Provincial boundaries are filled up with code. This system can transfer the regional vector data of every administrative counties (cities) of Hebei Province, with Arcview SHP form and Gauss- Craig projection.

When the disaster that low temperature and spare sunlight is identified by the indexes, it is necessary to show the occurrence region and its intensity. When there are different levels of early warning of disasters, the regions corresponding to the county (city) would be given the appropriate color (No disaster, no color display) based on the early warning levels of sites and by using geographical information technology to achieve the purpose of disaster warning. For example, the early warning result of the next three days on November 23, 2006 was illustrated in Fig.5.

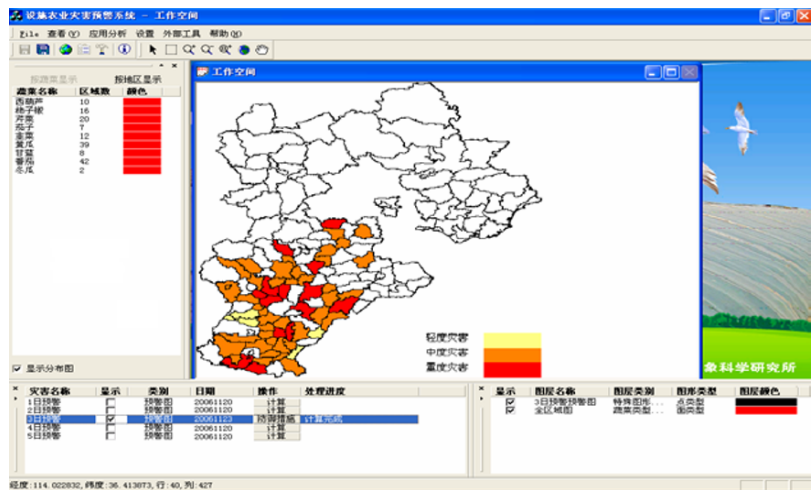


Fig.5. The early warning result of the next three days on November 23, 2006

6. CONCLUSIONS

GIS-based Disaster Warning System of Low Temperature and Spare sunlight in greenhouse, using C/S structure, with the functions such as meteorological data acquisition, the information inquiry, disaster warning, early warning test, document generation services, servicing measures inquiry, disaster statistics, early warning test and so on. The operational application of the system made the meteorological service quality and effectiveness, as well as the automation of disaster early warning have been improved.

The operational service of the system might provide a scientific basis for decision-making to the agricultural production department and leaders directing the agricultural production.

According to the development of modern agricultural facilities, the system will need to be improved in order to play a major role much better in the meteorological services for agriculture.

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STUDY ON FOREST VEGETATION CLASSIFICATION BASED ON MULTI- TEMPORAL REMOTE SENSING IMAGES

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Abstract: It is very difficult to classify forest vegetation in mountain areas because of the impact of complex terrain. A new method, classification of forest vegetation based on multi-temporal remote sensing, is proposed in this paper. The forest vegetation could get better classification precision by avoiding the interactions of different plants with multi-temporal images. So it enhanced the separability of coniferous forest and broadleaf forest. The classification result showed that the accuracy could be greatly improved by using multi-temporal remote sensing images. The overall accuracy and kappa coefficient were 81.3% and 0.72, respectively. So the method delivered in this essay has obviously technological advantages and important application potentiality in forest vegetation classification.

Keywords: multi-temporal, remote sensing, forest vegetation, classification

1. INTRODUCTION

The forest classification is an important aspect of the remote sensing application. Due to complexity of mountain topography, it was always a difficult problem to classify vegetation type, especially in mountain areas. In

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order to improve classification accuracy, some classification methods were studied by many experts and scholars at home and abroad in recent years. Chen, Y.H. et al. presented a synthetic approach to automatically derive classification knowledge with purpose of constructing a model of decision tree for final classification of the image. The result showed that the approach was far superior to the traditional maximum likelihood classification method (Chen, et al., 2006). Vegetation index was proposed to classify plant types. Yuan, J.G. thought that PVI could easily identify broadleaf forest and conifer forest, and the RVI difference was obvious in different coniferous forest species (Yuan, 1999). Wang, R.H. et al. studied the forest vegetation classification of TM image with the error back propagation (BP) model. The elevation channel, combining with the three multi-spectral channels, could improve the classification accuracy. Compared with the accuracy of the maximum likelihood classifier, the classification accuracy of spruce, pine and larch with error back propagation model was increased by 27.5% (Wang, et al., 2003). According to the relations between plant type and geographical environment factor, a knowledge-based vegetation classification was presented. Compared to the supervised classification method that does not use knowledge, the classification accuracy was increased about 9% using the knowledge-based method (Liu, et al., 1998). Mo, Y.F. et al. proposed a new method, sub-region classification, to deal with the remote sensing image classification in mountain areas. The result showed that the overall accuracy of sunshine classification was up to 83.16% and the shadow classification arrived at 64.45% (Mo, et al., 2000). In order to improve the vegetation classification accuracy of Landsat TM data in mountain area, vegetation classification supported by GIS data and phonological information is made by using four-seasonal TM data of maocer. The overall accuracy is increased by 19.6% compared to the classification result of single seasonal data (Huang, et al., 2004). Three-layer BP neural network was applied to study on wetland vegetation classification in cukurova Delta distinct. The classification overall accuracy was increased from 76% to 90.2% (Berberoglu, et al., 2004). Feature extraction and forest classification were completed using some methods such as fuzzy clustering method, stepwise regression and principal component analysis based on SAR data. The result showed that the classification accuracy was higher at 71.11% using fuzzy clustering method (Wu, et al., 2000).

These methods can improve the classification accuracy to some extent. The classification of remote sensing image mainly depends on the gray value difference of plants. Because of the phenomenon that the different plants with the similar spectral and the same plants with different spectral, it is hard to classify plant types using single temporal image. Especially in the mountain areas, the problem, the different plants with the similar spectral and the same plants with different spectral, is more serious because of

complex topography. Moreover, before classifying mountain plants, the fusion of remote sensing image and DEM data not only can correct the topography distortion, but also can improve the classification accuracy. In view of this, multi-temporal classification was proposed in mountain areas. Firstly, in order to correct the image distortion that was caused by topographic relief, Topographic correction to TM image was completed using DEM data. So the plant spectral difference which is caused by various terrain conditions can be reduced. Secondly, multi-temporal remote sensing data can fully use the time effect of spectrum signature among different plants. This technology could avoid the problem of “different spectrum with the same feature” and “different feature with the same spectrum” in some regions. The forest vegetation could get better classification precision by avoiding the interactions of different plants with multi-temporal images.

2. MATERIALS AND METHODS

2.1 Study area

Miyun is located in the northeast of Beijing ($N40^{\circ}13'7''-40^{\circ}47'57''$, $E116^{\circ}39'33''-117^{\circ}30'25''$), with the annual mean temperature at 10.8°C . MiYun is the biggest county of land area in Beijing. Its total area is 2229.45 km^2 , which covers 13% of the whole Beijing city. The mountain area is 1771.75 km^2 , accounting for about 79.5% of the whole county's area. The forest coverage rate is 47.33%. It is warm temperate continental climate of semi-dry and semi-humid. Its major vegetation type is warm-temperate deciduous broad-leaved forest and temperate coniferous forest.

2.2 Data pre-processing

It is necessary to preprocess the remote sensing data and terrain factor before forest vegetation classification with remote sensing. The main content of remote sensing data preprocessing are as follows: geometric correction, topographic correction, atmospheric correction and tasseled cap transform and so on. The terrain factor preprocessing is mainly acquisition of terrain factor using topographic map.

2.3 Image preprocessing

Considering image quality, temporal and spatial resolution, two TM images were acquired on April 1, 2004 and June 23, 2005 in order to classify

plant types in Miyun mountain areas. The two images were very clear without cloud or mist.

2.4 Geometric correction

The Landsat TM/MSS images were geometrically corrected using bilinear interpolation based on 1:1000 digital raster graphs, and the geometric precision was superior to one pixel.

2.5 Topographic correction

Due to the topographic effects in the mountain, the shadow of remote sensing image is especially serious. So it is needed to correct topographic effect. The topographic correction was achieved using moment matching algorithm in this paper. Digital elevation model (DEM) was selected to obtain the slope and aspect information, and the digital number (DN) values of the image in different slope and aspect ranges were corrected to the pixels in a referenced slope and aspect range (Zhong, et al., 2006).

2.6 Atmospheric correction

Firstly, the Empirical Line (EL) calibration method was employed for atmospheric correction to the TM image on July 23, 2005, and the TM image was converted from digital number to reflectance (Farrand, 1994). Secondly, the pseudo invariant objects, such as water, bare soil, dam, dense vegetation, were selected from the two Landsat TM/MSS images. Finally, the MSS image on July 14, 1979 was matched to the TM image on July 23, 2005 using the least squares regression method, and the MSS image was also converted from DN value to reflectance (Schott, 1988).

2.7 Normalized Different Vegetation Index

Normalized Different Vegetation Index (*NDVI*) is one of the most widely used in many vegetation indexes. It is the best indicator factor to reflect the crop condition and spatial distribution (Zhao, 2003). According to the characteristics that chlorophyll can significantly assimilate energy in red band and near infrared is sensitive to the difference of various green plants. *NDVI* is calculated by bands combination of red and near infrared. The formula is as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{1}$$

Where *NIR* is reflectivity of near infrared and *RED* is reflectivity of red band.

2.8 Tasseled cap transform

Tasseled cap transform is the effective separation of plant and soil by linear variable and spectral space rotation in the multi-dimensional spectral space. TC1 describes “soil lightness” and reflects soil spectrum information; TC2 denotes “greenness” and represents vegetation spectral information (Zhao, 2005). TM greenness of Miyun on June 23, 2005 was illustrated as fig.1.

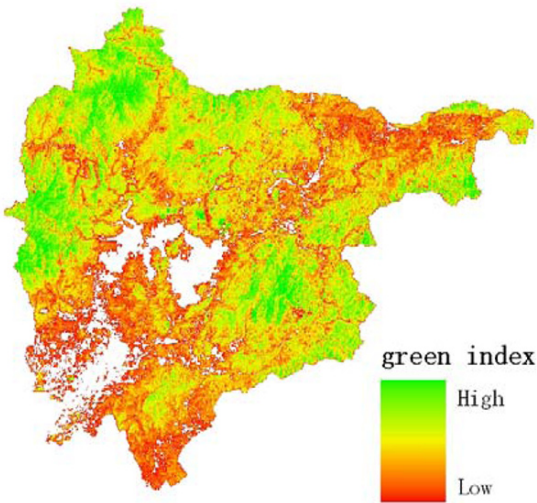


Fig.1 TM greenness on June 23, 2005

2.9 DEM data

The DEM data with a spatial resolution of 30m was converted from the digital contours of Miyun District at scale of 1:10000. Firstly, 1:10000 topography map was translated to digital image by scanner. Secondly, the vector contours was extracted from raster image by means of digital method. Finally, DEM data was obtained using interpolation of contours.

3. RESULTS

Considering the complexity of mountain terrain, it was advanced that a new classification method based on multi-temporal remote sensing data to classify plant type in mountain area. Comparing with the single temporal data, the multi-temporal data has obvious advantages in vegetation classification because it can reflect the change of the different season vegetation spectrum characteristics. Different plant types were classified using decision tree algorithm based on the combination multi-temporal data and terrain data (Technology roadmap of classifying plant types was illustrated as [fig.2](#)).

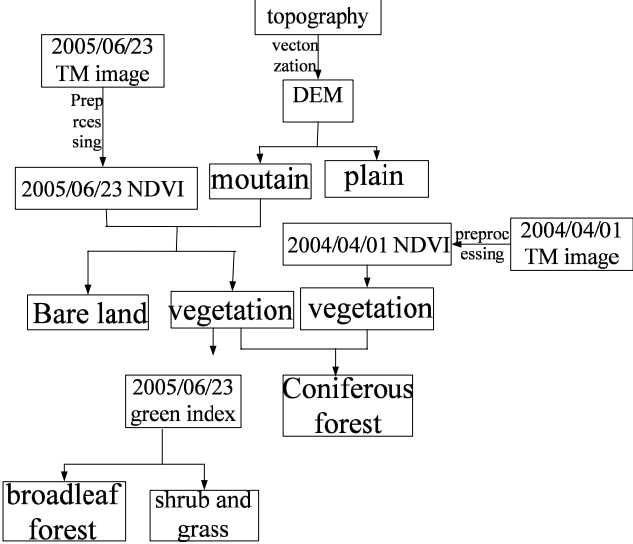


Fig.2 Technology roadmap of classifying plant types

First of all, the study area was divided into mountain and plain area. According to the actual situation in mountain areas of Miyun, the separatrix of mountain and plain area is 180 meters, namely, the region is mountain if DEM data is more than 180 meters, and otherwise, it is plain area. Secondly, in order to classify vegetation and nonvegetation, the right threshold was selected from NDVI image on June 23, 2005. Statistical analysis on the NDVI image on June 23, 2005 showed that vegetation and nonvegetation could be classified on the threshold of 0.3. On this basis, the different plant types in Miyun mountain areas were classified using NDVI and greenness on June 23, 2005 and April 1, 2004. The main plant types in Beijing are warm-temperate deciduous broad-leaved forest and temperate coniferous forest. Moreover, temperate coniferous forest has the evergreen characteristics. So

coniferous forest in Miyun mountain areas can be extracted using NDVI image on April 1, 2004. Thirdly, field investigation data of GPS was transferred to NDVI image on April 1, 2004. In order to extracted coniferous forest, the best threshold was selected by statistical analysis on NDVI value on April 1, 2004. The author found that extraction precision was higher with the threshold at 0.23. Finally, classification results were built mask, which was applied to greenness image on June 23, 2005. The broadleaf forest and shrub and grass were classified by selecting suitable threshold on the masked greenness image.

Table 1. area statistics of different plant types

Plant type	Ha	Area percent(%)
Broadleaf forest	67802.22	44.66
Coniferous forest	35452.62	23.35
Shrub and grass	48576.96	31.99
Total	151831.8	100

According to the theory that different plant type has different range of NDVI value and greenness index, the plant types of Miyun mountain areas, such as coniferous forest, broadleaf forest and shrub and grass, were extracted using NDVI image on April 1, 2004 and TM greenness image on June 23, 2005 (spatial distribution of different plant types was illustrated as fig.3 and area statistics was listed as table 1).

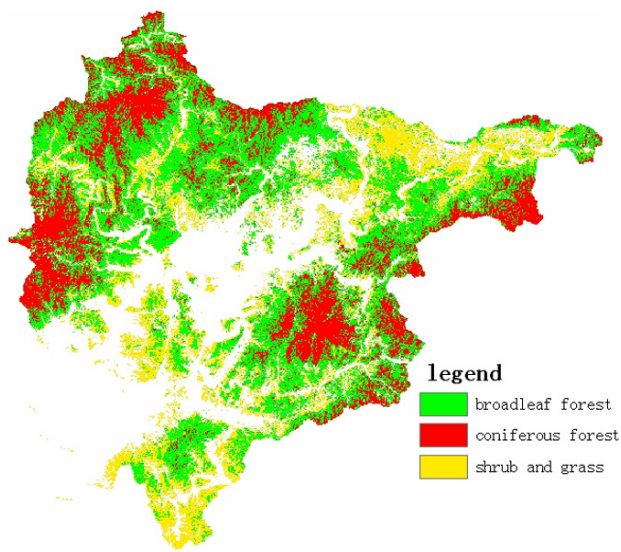


Fig.3 spatial distribution of different plant types

Classification result based on remote sensing image was verified using field investigation data. Accuracy analysis was completed by means of confusion matrix. Some accuracy estimating indexes, such as overall accuracy, user’s accuracy, producer’s accuracy and kappa coefficient, were calculated in the paper (precision estimation of forest vegetation classification was listed as [table 2.](#)).

Table2. precision estimation of forest vegetation classification

Category	Coniferous forest	Broadleaf forest	Shrub and grass	Total	User.acc(%)
Coniferous forest	128	15	12	155	82.6
Broadleaf forest	14	122	16	152	80.3
Shrub and grass	9	19	120	148	81.1
Total	151	156	148	455	
Prod.acc(%)	84.8	78.2	81.1		
Overall accuracy(%)	81.3		Kappa	0.72	

4. CONCLUSION AND DISCUSSION

Taking plants classification of Miyun mountain areas as an example, the feasibility, which plants classification based on multi-temporal remote sensing image, was researched in the paper. The forest vegetation could get better classification precision by avoiding the interactions of different plants with multi-temporal images. So it was enhanced that the separability of coniferous forest and broadleaf forest. The result showed that classification accuracy could be greatly improved using multi-temporal remote sensing image. The overall accuracy and kappa coefficient was 81.3% and 0.72, respectively.

Compared with classification of single temporal image, multi-temporal remote sensing data can fully used the temporal information. Moreover ,topographic factor is closely related to the vegetation distribution in mountain areas. Classification accuracy can be improved after comprehensively considering the effect of temporal information and topographic factor on plants classification in mountain areas.

Classification based on multi-temporal remote sensing images can improve precision to forest vegetation with distinct temporal difference. Some forest vegetations, such as broadleaf forest and shrub and grass, are deciduous in winter and green leaf in summer, the advantage of multi-temporal images classification can’t be embodied. It needs further researched that how to improve classification precision of broadleaf forest and shrub and grass.

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THE SPATIAL PATTERN CHARACTERISTICS OF SOIL NUTRIENTS AT THE FIELD SCALE

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Abstract: This paper took the wheat field of typical alluvial soil area as the research site, aimed to explore the spatial pattern of the soil nutrients, such as soil available potassium, soil available phosphorus, soil organic matter (SOM) and soil alkali hydrolysable nitrogen. With the help of DGPS, a total of 104 topsoil(0–20cm) samples were collected. Based on classical statistics, research results indicated the average content of soil available potassium was 287.476g/kg, the high value was 483.433g/kg, the low value was 119.435g/kg. The average content of soil available phosphorus was 54.228g/kg, the high value was 293.13g/kg, the low value was 18.77g/kg. The average content of SOM was 36.901g/kg, the high value was 47.420g/kg, the low value was 21.110g/kg. The average content of soil alkali hydrolysable nitrogen was 66.444g/kg, the high value was 166.474g/kg, the low value was 29.846g/kg. Geostatistical analysis, combined with geographical information system(GIS), the range, nugget and sill of soil nutrients characteristics were calculated, semivariogram model was established, ordinary kriging was applied, and the spatial distributing map of soil nutrients was drawn. It is shown that the semivariogram structures of the soil nutrients was spherical, the ratio of nugget/sill of soil available potassium, SOM, soil alkali hydrolysable nitrogen was 0.399, 0.746 and 0.696, respectively, which belonged to the middle intensity, the ratio of nugget/sill of soil available phosphorus was 0.759, which belonged to the low intensity. Spatial variation of soil available potassium was mainly caused by structural factors(parent material, terrain, climate, water table etc.), the structure variability of it took 60.1% of the total variability, the spatial variation of soil available phosphorus, SOM and soil alkaline hydrolysis nitrogen were mainly caused by random factors(fertilization, environmental pollution, cultivation measures, management etc.), the random variability of them took 75.9%, 74.6%, 69.6% of the total variability, respectively, the spatial correlation

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distance of SOM, soil alkaline hydrolysis nitrogen, soil available potassium and soil available phosphorus was 44.898 m, 45.191 m, 57.691 m and 23.328 m, respectively.

Keywords: soil nutrients, spatial variability, GIS, precision agriculture

1. INTRODUCTION

Spatial variability of soil characteristics benefits to comprehend the relationship between soil and environment, solve the problems about agriculture and resource management. With the rapid development of precision agriculture, the analysis of spatial distribution pattern of soil nutrients is becoming a focus and getting more and wide attention. To analyze spatial variability and pattern of soil nutrients is not only the foundation of practicing precision agriculture, but also is necessary for realizing the sustainable development of agriculture. In recent years, kriging techniques have been widely applied in soil, ecological, and environmental sciences to analyze the spatial patterns and variability of all kinds of properties. Some examples of kriging in soil nutrients include studies by some researcher([Gallardo, 2003](#); [Ouyang et al., 2006](#); [Guerra, et al., 2007](#); [Li Rui, et al., 2007](#)). However, the spatial distribution pattern of soil nutrients characteristics in the wheat field of the typical alluvial soil area has been rarely reported. Therefore, we chose a wheat field for revealing the spatial variability of soil available potassium, soil available phosphorus, SOM, soil alkali hydrolysable nitrogen, for estimating soil typical properties and mapping them, and for planning rational fertilization schemes.

2. MATERIALS AND METHOD

2.1 Experimental field and sampling laboratory treatment

The study was conducted in a typical alluvial soil area in the Yellow-Huaihe Rivers Plain region, experiment site was carried out at the field(117 ° 04.130'E, 36 ° 42.979'N), covering approximately 3 hm², located on the north shore of Xiaoqing River in Shandong province, P.R. China. This study area belonged to the warm temperate zone of half moist monsoon climate region, the terrain slope was high in the south and low in the north, and the soil was sandy clay loam. 104 soil samples were collected from the surface

layer (0–20cm) in June of 2007. Basically according to gridding sampling, each soil sampling was collected as a composite of 4 samples taken from the soil surface within a 5m circular area centered on each site. All soil samples were analyzed for soil nutrients by the key laboratory of plant nutrient and fertilizer in Shandong province, soil pH was measured in 1:2.5(soil: water) suspensions with a pH meter, soil available potassium was measured using flame photometric method, soil available phosphorus was analyzed with colorimetry, SOM was analyzed by potassium dichromate volumetric method, soil alkali hydrolysable nitrogen was measured by diffusion method, the concrete analysis process referred to the book "Analytical Methods for Soil and Agricultural Chemistry" (Lu Rukui, 1999).

2.2 Descriptive statistics of collected data

The descriptive statistical parameters and normality tests were calculated with SPSS (version 15.0) and Origin8.0. Kriging estimation were mapped within Surfer 8.0(Golden Software), ArcGIS8.3 and its extension of geostatistical analyst, spatial patterns of soil nutrients was visualized by the different classes. Location of each sample point was measured with a simple differential global positioning system (DGPS) to obtain latitude and longitude values, detailed records were made on the coordinates of the sampling sites, these were converted to a metric coordinates. Sampling site geo-positions were transformed into ".shp" format, which is compatible with ArcView, and underwent ArcGIS8.3 projection transformation into plane coordinates, based on meters. The sampling map was used for geostatistical analysis.

The analysis of normality test is the prerequisite of kriging interpolation to calculate the real values of semivariogram. The study carried on the normality test of the soil nutrients content with P-P normal probability plot, there is the normality about the soil available phosphorus and the SOM, the soil available potassium and the soil alkaline hydrolysis nitrogen after logarithm transformation. So soil nutrients concentrations passed the P-P normal probability plot, which suggested that normality test had been achieved and could basically meet the requirements of geostatistical analysis(Yang Yujian et al., 2005; Li Xiaoyan, 2007). We calculated some parameters of 104 sampling data such as classical statistics (arithmetic means, standard deviation, coefficient of variation, minimum and maximum, median, skewness and kurtosis). Descriptive statistics of the measured properties are presented in Table1.

There are three classes about coefficient of variation(C.V.), weak variation (C.V.<0.1), medium variation(C.V.=0.1–1.0), strong variation (C.V.>1.0). Coefficient of variation of soil nutrients content, respectively (Yang Yujian, et al., 2005) . C.V. of soil available potassium content, SOM

content and soil alkali hydrolysable nitrogen content, was 0.237, 0.136, 0.246, respectively, which belonged to the medium variation. C.V. of the soil available phosphorus content was 15.285, belonged to the strong variation. Table 1 showed that the study illustrated the characteristics of soil nutrients rather than the regional characteristics of the whole study area. This means that they cannot illustrate the spatial structural characteristics and the random variation of soil nutrients. Consequently, it is necessary to apply geostatistical methods together with GIS to solve this problem.

Table 1. Statistics characteristics of soil nutrients content

Item	Mean	Max	Min	Std. D	Var.	Skew.	Kur.	C.V.	Dis.
SOM	36.901	47.420	21.110	5.000	25.004	-0.655	0.811	0.136	N
N	66.444	166.474	29.846	16.346	267.191	1.988	12.891	0.246	logN
K	287.475	483.433	119.435	68.286	4662.99	0.463	0.381	0.237	logN
P	4.23	293.13	18.77	28.790	828.860	5.676	45.981	15.285	N

Notes: N stands for normal distribution; logN stands for normal distribution after logarithm transformation

2.3 Geostatistical analysis of study data

A semivariogram, which graphs the semivariogram between spatially separate data points as a function of the distance is well documented to illustrate the spatial relationship of soil properties. It represents the relationship between the lag or any integral multiple of the sampling interval and the semivariogram. Semivariogram is theoretically shown as follow:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^n [Z(x_i + h) - Z(x_i)] \tag{1}$$

Where: the $\gamma(h)$ quantity is function only of the increment h , $N(h)$ is the numbers of pairs separated by a distance h , $Z(x_i)$ and $Z(x_i + h)$ are the sampled values at location x_i and $x_i + h$ for the analysis. The concepts and the theory of geostatistics referred to " Geostatistics in Environmental Science and its Application" (Zhang Renduo, 2005). Semivariograms revealed the spatial structure for all studied properties. The theoretical localized discontinuity or nugget, C_0 , is defined by the y-intercept and is interpreted as variability due to experimental error, distributed effects below the sampling scale of the study, and other random effects. The corresponding value of the semivariogram at this point is termed the sill($C+C_0$) and represents the combination of a nugget effect and variability(C) attributable to spatial dependence. The ratio of nugget value (C_0) to sill value ($C_0+ C$) is an important index for investigating the spatial structures of soil properties(Cation, 2001). In the study, there were only four soil properties for which we obtained reasonably accurate and effective predictions, including soil available potassium, soil available phosphorus, SOM and soil

alkaline hydrolysis nitrogen. The semivariograms of soil nutrients exhibited excellent spatial structure, which could be well fitted with a spherical model, the parameters of spherical model were displayed in [table 2](#).

Table 2. Structure parameters of semivariogram and validation of soil nutrients model

Var.	Model	C ₀	C ₀ +C	Range(m)	C ₀ / C ₀ +C	Estimated error				
						ME	RMSE	ASE	MSE	RMSSE
SOM	S	11.066	14.834	44.898	0.746	0.04831	4.042	4.123	0.009659	0.9798
N	S	0.0270	0.0388	45.191	0.696	0.2592	15.15	14.11	0.001071	1.079
K	S	0.0183	0.0457	57.691	0.399	-0.3519	52.61	52.35	-0.01118	1.012
P	S	120.77	159.15	23.328	0.759	0.1904	14.69	14.84	0.01101	0.9925

Note: S stands for spherical model.

The degree of spatial autocorrelation was described by the ratio of nugget and sill, if the ratio is smaller than 25%, suggested the system has the intense spatial autocorrelation; if the ratio between 25%~75%, indicated the system has the medium spatial autocorrelation; if higher than 75% suggested the weak spatial autocorrelation. According to [table 2](#), the ratio of nugget and sill of SOM, soil alkaline hydrolysis nitrogen, soil available potassium and soil available phosphorus were 0.746, 0.696, 0.399 and 0.759, respectively. Results showed there was the medium spatial autocorrelation of SOM, soil alkaline hydrolysis nitrogen, soil available potassium, the weak spatial autocorrelation of soil available phosphorus. [Fig.1](#) shows the semivariogram model of soil available potassium, soil available phosphorus, SOM and soil alkaline hydrolysis nitrogen , respectively.

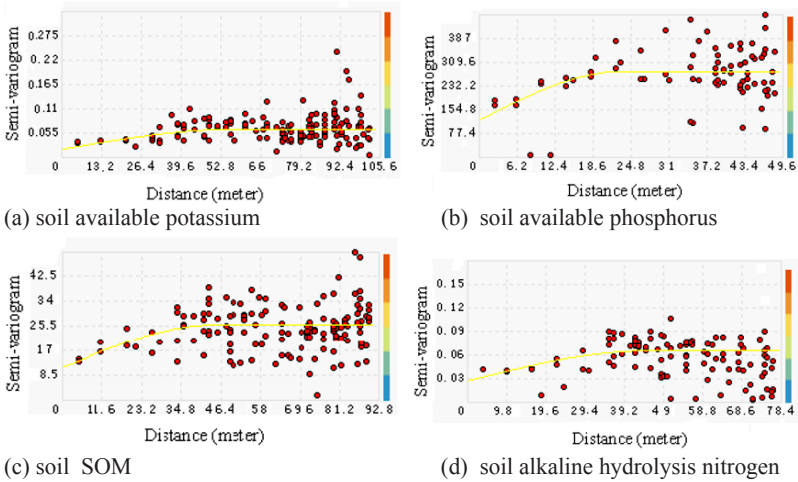


Fig. 1. Semivariogram model of soil nutrients

A semivariaogram model is only an approximation of the spatial variability of the measured conditions, an indication of how well our semivariogram model approximates the experimental semivariogram is appraised by means of cross-validation procedure, cross-validation was used

to obtain study by better resolving the spatial structure predicted and measured values, in this case a kriging estimation is made and compared with measurements. Thus, if for every one of the locations where we have a measured value, $Z(x_i)$, we estimate a value, $Z'(x_i)$, then standard value of them were $Z_1(x_i)$ and $Z_2(x_i)$, then the expression of their average error, the average standard error, the root-mean-square error and the standardized root-mean-square error were

$$ME = \frac{1}{N} \sum_{i=1}^N [Z(x_i) - Z'(x_i)] \quad (2)$$

$$MSE = \frac{1}{N} \sum_{i=1}^N [Z_1(x_i) - Z_2(x_i)] \quad (3)$$

$$ASE = \sqrt{\frac{1}{N} \sum_{i=1}^N \left[Z'(x_i) - \left(\sum_{i=1}^N Z'(x_i) \right) / N \right]^2} \quad (4)$$

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N [Z(x_i) - Z'(x_i)]^2} \quad (5)$$

$$RMSSE = \sqrt{\frac{1}{N} \sum_{i=1}^N [Z_1(x_i) - Z_2(x_i)]^2} \quad (6)$$

If ME(Mean standardized error) of the model approaches 0, ASE(Average standard error) approaches RMSE(Root-mean-square error), MSE(Mean standard error) approaches 0, RMSSE(Root-mean-square standardized error) approaches 1, which verifies the goodness of the fitted semivariogram models, estimated error of parameters of spatial pattern prediction referred in [table 2](#). (Yang Yujian, et al., 2005; Zhang Wei, et al., 2007).

3. RESULTS AND ANALYSIS

Based on the fitted semivariogram, we used ordinary kriging interpolation methods and acquired the spatial distribution maps of soil nutrients content at the field scale. [Fig.2](#) shows the interpolation map revealed remarkable differences in the size, shape, and spatial distribution patterns about soil nutrients in the research area. Generally speaking, there were many factors affecting the spatial variation of soil nutrients, including structural factors (parent material, terrain, climate, water table etc.) and random factors (fertilization utilization, environmental pollution, cultivation measures, management etc.). From the above analysis, the study established

the spatial distribution model of soil nutrients, the best fitted of spherical. Research results indicated that structural factors were the main factors of the spatial correlations of soil available potassium, the structure variability of it took 60.1% of the total variability, the spatial variation of soil available phosphorus, SOM and soil alkaline hydrolysis nitrogen were mainly caused by random factors, the random variability of them took 75.9%, 74.6%, 69.6% of the total variability, respectively, the spatial correlation distance of SOM, soil alkaline hydrolysis nitrogen, soil available potassium and soil available phosphorus was 44.898 m, 45.191 m, 57.691 m and 23.328 m. The paper also described the spatial distribution of soil nutrients characteristics. The spatial distribution pattern of soil nutrients(Fig.2), there is high value content of soil available potassium in the southeast and middle of the filed, soil available phosphorus in the middle of the filed, SOM in the southwest, northwest and middle of the field and soil alkaline hydrolysis nitrogen in the southeast and middle of the research site.

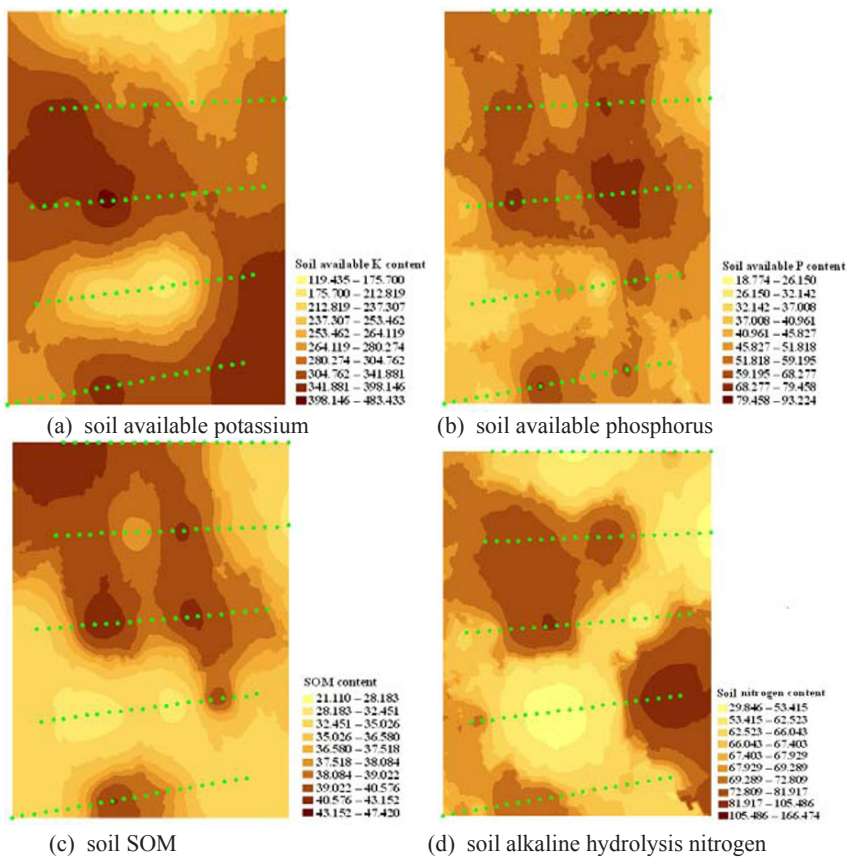


Fig.2: Spatial distribution pattern of soil nutrients at the field scale

There was the different soil characteristics in the different terrain, the spatial distribution of soil available potassium was relatively great affected by the micro-relief in the research site, as well as the absorption of crops, washing of soil nutrients and conditioner of soil pH in study field. There was a high value of SOM content in the southwest at the wheat field, where the irrigation canal flowed, in addition, organic matter stack became an important method of SOM increasing, according to the practical investigation, high organic fertilization also succeeded to the location of the history. Soil available phosphorus has two high value areas in the middle of the field, as the center, from inside to outside of its content presenting the distribution from high to low. From the scope of spatial scales, there was the low content in the southwest and northeast of the field, concerned with the closely irrigation canal, which affected the distribution of soil available phosphorus content, the distribution of it was concerned with present phosphate fertilization condition, for the small mobility of soil phosphorus, as well as the low fertilization utilization of the same season, resulting into the balance of soil phosphorus and the more phosphorus remains in soil, then forming the unevenly spatial distribution of soil phosphorus. The crop growth was affected nitrogen absorbing of crop, there is high value of soil alkaline hydrolysis nitrogen in the southeast and middle of the field, mainly for it. The investigation suggested the wheat growth is better than other places of the same field, the important factors of unbalance of soil alkaline hydrolysis nitrogen content was caused by the unbalance of fertilization, including nitrogen and organic fertilizer accumulation.

4. CONCLUSIONS

With the support of classical statistics, analysis results of 104 topsoil soil samples indicated that the average content of soil available potassium, available phosphorus, SOM and soil alkaline hydrolysis nitrogen was 287.476g/kg, 54.228g/kg, 36.901g/kg and 66.444g/kg, respectively at the field scale. The paper also clarified the spatial distribution pattern of soil nutrients in the paper, research results indicated that structural factors were the main factors of the spatial autocorrelations of soil available potassium, the structure variability of it took 60.1% of the total variability, the spatial variation of soil available phosphorus, SOM and soil alkaline hydrolysis nitrogen were mainly caused by random factors, the random variability of them took 75.9%, 74.6%, 69.6% of the total variability, respectively. Results showed different spatial distribution pattern of different soil nutrients at the field scale, there is high value content of soil available potassium in the southeast and middle of the field, soil available phosphorus in the middle of the field, SOM in the southwest, northwest and middle of the field and

soil alkaline hydrolysis nitrogen in the southeast and middle of the research site, the prediction results of model and actual fertilization are concordant.

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RESEARCH ON PRECISION IRRIGATION IN WESTERN SEMIARID AREA OF HEILONGJIANG PROVINCE BY INTERPRETING DATA SOURCE SPATIAL DISTRIBUTION

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Abstract: Geostatistics and geographic information system (GIS) were performed to characterize the spatial variability of soil water characteristics in western semiarid area of Heilongjiang Province and delineate the spatial distributions of the variables. On the basis of data source spatial distribution and professional knowledge, the study site was divided into four irrigation management zones. Then stratified sampling method and optimal distribution method were used to calculate the rational sampling number in each sub-zone and rational sampling scheme was designed combining with the ranges of regionalized variables. During the course of practicing precision irrigation, irrigation scheme can be designed by measuring natural water content in each sub-zone and comparing with saturated water content, field water capacity and wilting point in the same area.

Key words: management zone, precision irrigation, sampling scheme, spatial variability

1. INTRODUCTION

Precision irrigation, based on 3S technique and geostatistics theory, is an integrated irrigation technology system to real-timely and appropriately

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irrigation according to soil moisture and water requirement of various crops in different growth periods, by utilizing macroscopic control of RS, functions (collecting, storing, analyzing and outputting element data required by ground or plot) of GIS and ground precision measurement of GPS, then matching ground information transformation and real-time control system (Cheng, 2004).

Owing to various and complex demands of precision irrigation (soil moisture, water requirement condition and variable irrigation technique), it is difficult to research and practice precision irrigation. Few researches about precision irrigation were reported abroad, and it was in starting stage in China (Tian et al., 2002). Liu et al. (2006) expounded the research significance and prospect of precision irrigation in China. Liu (2000) used GPS water saving irrigation system to study precision irrigation. Sun et al. (2004) practiced real-time and appropriate precision irrigation during whole cotton growth period based on under-film automatic trickle irrigation system in cotton field and provided hardware supports for precision irrigation. Hu (2004) established real-time irrigation forecast model for irrigation district and obtained precision prediction results. Han et al. (2003 and 2004) made a lot of researches on variable irrigation sprinkler and developed an impact sprinkler with non-circular spray field. A great deal of researches were made on precision irrigation system and equipment by domestic scholars, but few studies, however, reported the quantitative research on field precision irrigation management zone and irrigation water use.

Thus, the objectives of the study were to characterize the spatial variability of soil water characteristics in western semiarid area of Heilongjiang Province, to delineate irrigation management zone for study site based on data source spatial distribution by utilizing geostatistics, GIS and sampling technique, and to practice precision irrigation by measuring natural water content in each sub-zone.

2. MATERIALS AND METHODS

2.1 Site description and soil sampling

The study was conducted on a soybean field of 1 ha in the dry cultivation techniques demonstration district of Chahayang Farm, which is in the western semiarid area of Heilongjiang Province. It is located in the cold temperate zone, continental monsoon and semiarid agricultural climate region, and is windy and arid in spring. Thus precision irrigation practiced in the region is magnitude.

A grid-sampling scheme was imposed on the field to collect 300 soil samples from three layers in the topsoil (0-30 mm) at an interval of 10 m in the autumn of 2006 after crop harvesting. One representative sample was collected at the center of each grid and geo-referenced using a Trimble global positioning system (GPS) with differential correction. Five indices, such as natural water content (NWT), field moisture capacity (FMC), saturation moisture content (SMC), wilting point (WT) and soil dry bulk density (SDBD), were measured for three layers soil samples in each sampling position, and the mean of them was considered as the soil water characteristics values of the point.

2.2 Geostatistics

In 1970s, geostatistical method was introduced into soil science field, which overcame the deficiency researching spatial variability of soil characteristics on the basis of classical Fisher statistics theory. Geostatistics is a branch of science based on a series of concepts (regionalized variable, random function, stationarity hypothesis, etc.), to take semi-variogram as main tool and kriging interpolation method as instrument, to study natural phenomena having random and structural spatial distribution or spatial correlation and dependence (Hou et al., 1993). Semi-variogram and kriging interpolation map in geostatistics can be used to determine variation extent and spatial correlation scale of soil properties, to estimate spatial distributions of soil characteristics and to provide guiding significance. Presently, it is one of the trends to apply the theory and method of geostatistics in quantitative research on soil spatial variability.

2.3 Sampling technique

Under a range of sampling error, different sampling method is needed for various sample numbers and requirements to reflect the property of population as much as possible with the least samples. Simple random sampling and stratified sampling are the most adopted sampling techniques. Random sampling is simple and intuitionistic, but has low estimation efficiency for population, while stratified sampling has higher estimation precision, which can estimate population index and layered index simultaneously and carry out different sampling methods among layers. Thus, stratified sampling method was performed in the study for sampling investigation of the soil water characteristics (Jin et al., 2002). The optimal

distribution method is used to determine the sampling number of each layer. The calculation equations are as follows.

$$\text{Total sample size: } n = \frac{(\sum W_h S_h)^2}{V + \frac{\sum W_h S_h^2}{N}},$$

$$\text{Distribution of sample size among layers: } n_h = \frac{N_h S_h}{\sum_{h=1}^L N_h S_h} \times n,$$

Where: $W_h = \frac{N_h}{N}$ and $V = (\frac{d}{t})^2 = (\frac{r\bar{Y}}{t})^2$; W_h , N_h and S_h are the weight, observation number and standard deviation of the h th layer respectively; N is the observation number of population; V is the variance from sample estimation; d is absolute error; r is the relative error; $\bar{Y}$ is the mean value of population and t is the bilateral α quantile of standard normal distribution.

3. RESULTS AND DISCUSSION

3.1 Spatial variability analysis of data source

The contents of spatial variability analysis include calculating semi-variogram, fitting semi-variance model and estimating non-sampling area for regionalized variable (Zhang, 2006). Through analyzing the parameters of semi-variance model, we can sufficiently find out the variation condition and influencing factors of regionalized variable. Spatial partial estimation is to use kriging method to interpolate in non-sampling area and delineate spatial distribution for regionalized variable, which can intuitionistically illuminate the spatial distribution situation of regionalized variable. Calculating semi-variogram and fitting theoretical model were conducted in a geostatistical software (GS+) and the results are listed in Table 1. ArcGIS software is used to complete spatial partial estimation and the maps are showed in Fig.1.

Table 1. Models and parameters of semivariograms for soil water characteristics

SWC ^{a)}	Fitted model	Nugget variance (C ₀)	Sill variance (C ₀ +C)	Nugget/Sill Ratio [C ₀ /(C ₀ +C)] (%)	Range(m)	CD
NWC	Exponential	0.68	2.30	29.52	30.3	0.967
FMC	Spherical	0.57	2.63	21.49	23.4	0.938
SMC	Spherical	4.80	23.19	20.70	19.1	0.878
WP	Spherical	0.11	0.53	20.64	94.2	0.934
SBDB	Spherical	0.001	0.005	22.92	19.2	0.829

^{a)} SWC, soil water characteristics; CD, coefficient of determination

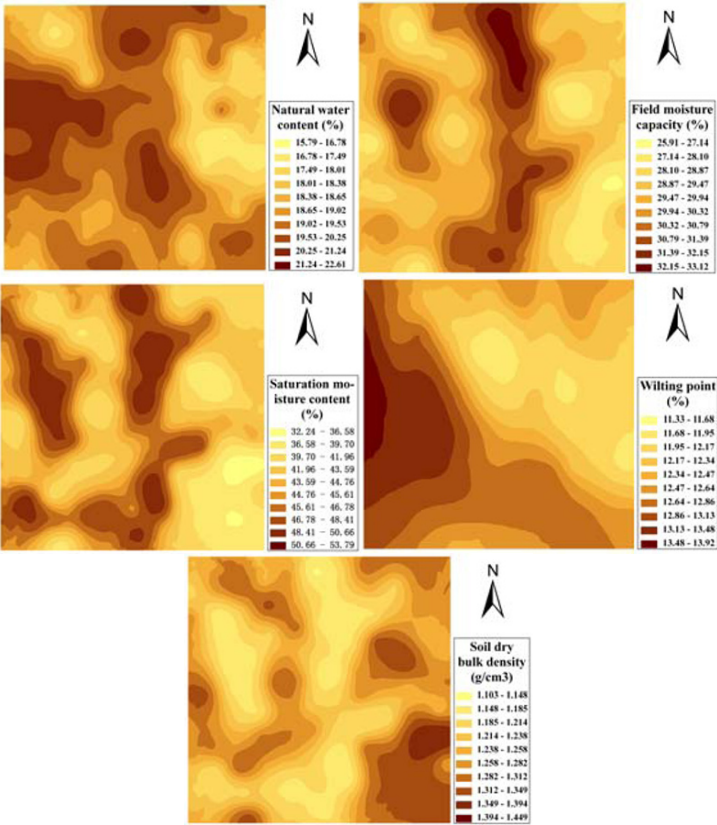


Fig.1. Spatial distributions of soil water characteristics

The optimal theoretical model of natural water content was exponential model, whereas the other soil water characteristics were all best fitted to spherical models. The coefficient of determination of soil water characteristics were greater than 0.829 indicating a high degree of modeling confidence. The nugget/sill ratio $[C_0/(C_0+C)]$ can describe the proportions of random factors and structural factors to system total variability, and can characterize the variable degree of regionalized variables more intuitionistically comparing with the coefficient of variation (Jiang et al., 2007). The nugget/sill ratio of natural water content was 29.52% suggesting moderate variability (25%-75%), while the other soil water characteristics showed weak variability (0-25%), which indicated that in the variation of natural water content, random factors accounted for a large percentage, namely, it was mainly affected by climate and artificial factors. For the five characteristics the ranges have changed greatly, and wilting point had the

biggest range of 94.2 m while saturation moisture content had the smallest range of 19.1 m, which indicated that the grid spacing (10 m) in the study was adequate for characterizing the spatial variability of soil water characteristics.

Field moisture capacity, saturation moisture content and soil dry bulk density had a similar spatial distribution presenting bandings, and the last index was negatively correlated with the other two indices, namely, soil dry bulk density had small values in the region where the other indices with big values. Through the course of correlation analysis, the correlation coefficients of soil dry bulk density to saturation moisture content and field moisture capacity were -0.98 and -0.85 respectively, which confirmed the spatial variability relations among them. The spatial distributions of natural water content and wilting point presented sheets.

3.2 Delineating precision irrigation management zone

Implementing different irrigation schemes based on various soil moistures is the aim of precision irrigation. For field moisture capacity, saturated moisture content and wilting point are important indices to determine irrigation water use and whether to irrigate, the three water characteristics are essential during delineating irrigation management zone. Homogeneous soil water characteristics in the same sub-zone and easy field management are principles to delineate the study site. Owing to sheet spatial distribution of FMC and SMC and north-south ridge in the field, the study area was divided into four oblong sub-zones listed in Fig.2, where zone III had the biggest area of 3000 m², zone II had the smallest area of 2000 m², and zone I and zone IV had the equal area of 2500 m².

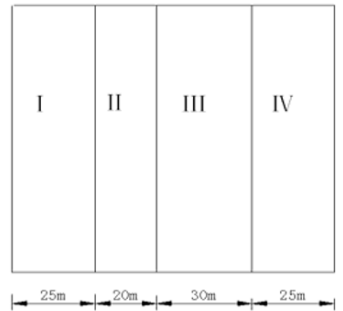


Fig.2: Sketch map of irrigation management zone for study site

For differences existed among soil water characteristics of each sub-zone after delineation, statistics analysis is needed to realize them roundly. Table 2 lists the results. Through comparison of mean values, the sequencing of NWC was zone I > zone III > zone II > zone IV, namely, soil moisture of zone I was best when samples were collected, while that of SBDB was zone

IV > zone II > zone I > zone III. The smallest values of NWC, FMC, SMC and WP in zone IV indicated that the sub-zone had bad soil moisture condition and water retaining capacity owing to the high SBDB in the area leading to dense granule sequencing and small permeability, so deep tillage is essential for the area to decrease SBDB. FMC and SMC were biggest and SBDB was smallest in zone III, which illuminated that the surface soil of the area had strong water capacity and good quality. After analyzing the variation coefficient in each sub-zone, we found that the variation coefficients of all soil water characteristics expect for NWC decreased in different extent after delineation, which showed that differences in the same sub-zone were smaller than that of total area.

Table 2. Statistical eigenvalue of soil water characteristics in each sub-zone

Sub-zone	Sample number	SE ^{a)}	NWC (%)	FMC (%)	SMC (%)	WP (%)	SBDB (g/cm ³)
Zone I	225	Mean	19.45	29.64	45.33	13.12	1.238
		CV (%)	4.88	3.14	5.85	2.44	3.23
Zone II	180	Mean	19.27	29.8	43.69	12.64	1.247
		CV (%)	3.22	2.28	4.92	3.01	2.41
Zone III	270	Mean	19.32	30.74	45.78	12.38	1.216
		CV (%)	3.67	2.99	6.14	2.42	3.29
Zone IV	225	Mean	18.46	28.67	40.53	12.28	1.292
		CV (%)	4.01	2.65	6.81	1.95	3.10
Total area	900	Mean	19.12	29.74	43.87	12.59	1.248
		CV (%)	4.55	3.83	7.75	3.57	4.01

a) SE, statistical eigenvalue; CV, coefficient of variation

Single factor unequal repeated test was conducted based on grid data among sub-zones to estimate whether differences were remarkable or not. The results listed in Table 3 showed very significant difference between sub-zones, where the value of *F* of WP was biggest while that of NWC was smallest. Though the significance of NWC was not strong, it met the variance test of very significance. The results of variance analysis illuminated that delineation based on spatial distributions of soil water characteristics showed good homogeneity in a sub-zone and significant heterogeneity between sub-zones and obtained favorable results.

Table 3. Single factor variance analysis of soil water characteristics among sub-zones

Statistics test	NWC(%)	FMC (%)	SMC (%)	WP (%)	SBDB(g/cm ³)
F	73.71	220.22	181.71	310.69	140.28
Pr >F	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Significance	Very	Very	Very	Very	Very

3.3 Designing sampling scheme

Rational sampling number and spatial position of sampling point are two main aspects that should be considered in design of sampling scheme (Wollenhaupt et al., 1997). Due to various mean, coefficient of variation (CV) and standard deviation between sub-zones, optimal distribution method of stratified sampling was carried out to calculate and distribute rational sampling number for sub-zones. Results obtained at the confidence level of 95% and in the relatively tolerable error of 5% are listed in Table 4. The rational sampling quantity ascertained by stratified sampling method has decreased by 88%-97% compared with the original in the study site, which consumedly saved manpower and material resources and reduced invest for precision irrigation practice.

Table 4. Rational sampling number of each sub-zone

Sub-zone	NWC	FMC	SMC	WP	SBDB
Zone I	2	1	4	1	1
Zone II	2	1	3	0	1
Zone III	2	1	4	1	2
Zone IV	2	1	4	1	1
Total zone	8	4	15	3	5

Rational sampling scheme has to match rational sampling number and ensure distance between samples larger than range of the variable. On the basis of these principles, sampling scheme was designed and showed in Fig.3. The three sampling points of WP located at the intersections of northwest to southeast diagonal and the midlines of zone I, zone III and zone IV, respectively. The four sampling points of FMC located at the intersections of southwest to northeast diagonal and the midlines of all four sub-zones. The distances from the sampling point of SCM at northeast corner to north side of the field, from sampling point at southwest corner to south side, and from point to point on the north-south direction were 10 m, 15 m and 25 m, respectively. The spatial locations of sampling point of NWC are showed in Table 5.

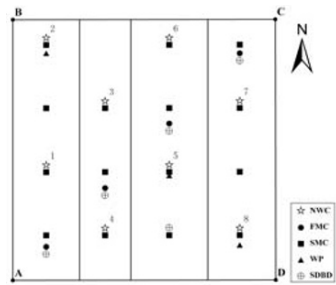


Fig.3: Sampling scheme map for the study site

Table 5. Spatial positions for natural water content in the scheme

Point	Relative coordinates (m)		Point	Relative coordinates (m)	
	X	Y		X	Y
A	0	0	5	60	40
1	12.5	40	6	60	90
2	12.5	90	7	87.5	65
3	35	65	8	87.5	15
4	35	15	C	100	100

3.4 Practicing precision irrigation

Because NWC extremely influenced by climate has strong temporal variability, it just reflects the soil moisture condition when sampling scheme is performed, while the other soil water characteristics related to soil parent material and grain composition have relatively temporal stability. Thus, NWC measurements are available and efficient for precision irrigation decision-making. The measurement of NWC can be performed based on field soil sampling or soil moisture monitoring system installed in field for long term monitoring, where the burying quantity and location of monitoring system can be carried out on the basis of the sampling scheme of NWC.

During the course of practicing irrigation, comparing the monitored means of NWC of each sub-zone in the study site with the means of FMC, WP and SMC in Table 2, we can then make a decision on precision irrigation, namely, when NWC is between FMC and SMC, irrigation is unnecessary, and when it is less than FMC and approaching WP, irrigation is needed and the upper irrigation limit is FMC in each sub-zone. Additionally, when water supply is plenteous, 70% of FMC can be taken as the lower irrigation limit, however, if water-saving irrigation techniques are adopted, the lower irrigation limits are the lowest values of appropriated moistures in different growing stages obtained according to demands of various crops and local water-saving irrigation experiments of main crops (Hu, 2004).

4. CONCLUSIONS

Aiming at the present situation of fewer researches on precision irrigation abroad and in home, on the basis of spatial variability of soil water characteristics, we combined spatial distributions of the variables with professional knowledge to divide the study area into four irrigation management zones and the analysis results indicated the delineation for the

study site was reasonable. To ensure the representation of sampling points, geostatistics and stratified sampling method were integrated to design rational sampling scheme. During the course of practicing precision irrigation, soil moisture monitoring system can be installed in the field based on the sampling scheme, and different irrigation schemes can be design by comparing the measurements of NWC with FMC, SMC and WP in each sub-zone.

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APPLICATION OF 3S TECHNOLOGY TO LAND CONSOLIDATION IN CHERNOZEM REGION OF CHINA

a case study of Hulun Buir

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Abstract: The chernozem has high productivity, most of which is located in Northeast of China. Considering the restrictions of land use and terrain and meteorological conditions, soil erosion and degradation often result in lower agricultural output than expected. Land consolidation is served to consolidate parcels and to enlarge holdings as well as included provisions such as irrigation, drainage infrastructure, in order to improve land leveling and productivity potential. Therefore, the purpose of our research is to maintain the productivity of cultivated land and to enhance the conservation of water and soil by way of land consolidation, with two case studies in Hulun Buir in Inner Mongolia Region. Northeast of China. Our research integrated Geographic Information System (GIS), Remote Sensing (RS) and Global Position System (GPS), and also introduced an optimized method which could save earthwork and reduce soil erosion risks with a holistic perspective considering cultivated land, water, road and forests land. The results showed that by using the optimized method, comparing to total plane method, the earthwork decreases by 3/4 and 7/8; for slant method, the reduced earthwork is 1/2 and 1/3. Meanwhile, this optimized method can also significantly reduce risk of surface land removal in chernozem land. This paper concluded that we should use 3S technology to find soil erosion area, and implement amending local topography method during cultivated land consolidation in chernozem area.

Keywords: land consolidation, GIS, chernozem region, Hulun Buir, China

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1. INTRODUCTION

Land, given by nature, is human beings' valuable resource and asset. Land resources are limited and non-renewable. It not only ensures human beings' life and development (Hao Jinmin, 1996, 2007; Zhu Daolin, 2000; Lars D. et al., 1992), but also bears great responsibility of national food security. In order to relief status of cultivated land decrease, China has begun to develop land consolidation since 2001, aiming to improve agricultural productivity and ensuring dynamic balance in whole nation's total cultivated land. Land consolidation is served to consolidate parcels and enlarge holdings and included provisions such as irrigation and drainage infrastructure to improve land leveling and soil. It has been achieved initial successes in China (Fan Min, 2006). However, the land consolidation project ignored the ecological construction.

At present, there are still few studies for land consolidation on chernozem region in China. This region has unique natural conditions and ecological environment, special ways of production and management. Recently China proposed the important issues of Northeast revitalization planning. It emphasized ecological comprehensive control of black soil area (i.e. area with black soil, chernozem and meadow soil), strengthening comprehensive control on soil and water loss, perfecting protection forest system around cultivated land, recovering grassland vegetation, modifying and fertilizing black soil, preventing non-point source pollution.

Chernozem was formed by meadow grassland vegetation through humus accumulation process of calcium carbonate eluviation and deposition under half moist climate. It is a kind of soil which surface is with black humus, but lower soil layer is with calcium horizon or with lime reaction (Lü Yizhong et al., 2006). The area of chernozem region in China is 134.216 million hm^2 (Liu Chunmei et al., 2006), mainly distributed in southwest part of Heilongjiang province, west part of Jilin province, northwest of Liaoning province and Hulun Buir City in eastern part of Inner Mongolia autonomous region. It means that chernozem region is mainly distributed in song-nen plain, both east and west side of Daxing'anling, and Songliao Divide region. (Fig.1.)



Fig.1. Chernozem major regional distribution of China

This paper selected agricultural land consolidation, on two typical landforms (valley plain, low mountain and hill) in Hulun Buir, as empirical studies. We studied agricultural land consolidation with holistic perspective of field, water, and road and protection forest comprehensively in chernozem region. Then we introduced an optimized design method of agricultural land consolidation compared to total plane method, which was prevalent across the whole nation. Finally we proposed some advices on agricultural land consolidation for chernozem region of China.

2. BACKGROUND OF THE STUDY AREA

Study area A and B respectively located in Yakeshi and Erguna, both in Hulun Buir in eastern part of Inner Mongolia autonomous region (Fig.2.). Study area A, in Yakeshi, is situated at Long. 121°08'42"-121°11'11" E, and Lat. 49°13'20"-49°15'15" N. Its total area is 1148.384hm². Micro topography of area A is plain, and average gradient is 1.2% (<2°), smaller in east-west direction. Annual average temperature is -2.2°C, annual average rainfall is 402.4mm.

Study area B, in Erguna, is situated at Long. 119°26'07"-119°28'52" E, and Lat. 50°12'11"-50°13'23" N. Its total area is 995.423hm². Micro topography of area B is low mountain and hill, and north-south average gradient is below 6.0%, east-west average gradient is below 5.0%, but fluctuation in south landform is relatively varied from 2-8° . Annual average temperature is -3.2°C, annual average rainfall is 497.5mm. Table 1, Table 2 show the soil properties of study areas (Pu Demao, 1993).

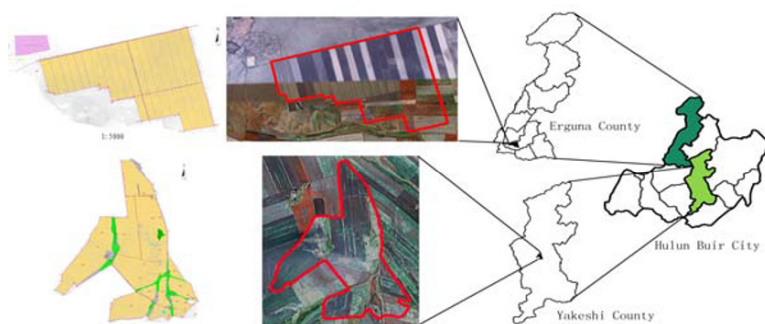


Fig. 2. Land Use Map and Location of Land Consolidation study areas

Per capita cultivated land in whole Erguna county is 0.19hm², and in Yakeshi county is 0.30hm² (Yakeshi Bureau of Statistics network, 2005). In the two study areas, per capita cultivated land is above 15hm²., which means

per capita cultivated land in study areas is very rich, but labors for agriculture is relatively few. So in order to solve the problem of labor force, agriculture producing mainly depends on farm economic organization to implement mechanized farming; meanwhile, it greatly improves agricultural production efficiency.

Both of above study areas are farm management mode, mainly depending farm economic organization on producing, with intensive mechanized farming. For the mechanical way of cultivate, and unsustainable management until now, the utility of chernozem nutrient is off balance, and the quality of soil is decreasing continuously which causes soil erosion, soil degradation and land desertification. This problem widely exists in China chernozem region.

Tab. 1. Meteorological characteristics of study area A and B

AREA	Average temperature ℃	≥0℃ accumulated temperature ℃	≥10 accumulated temperature ℃	Annual rainfall (mm)	Annual evaporation (mm)	Frostless period (d)	Annual average wind speed (m/s)	Soil freezing depth (m)
A	-2.2	2404.9	1815.6	460.0	1107.5	96.4	1.8-3.6	2.7
B	-3.1	2216.0	1767.0	397.5	1197.7	95.0	2.1-2.5	3.0

Tab. 2. Soil characteristics of study area A and B

AREA	Organic Matter content (g/kg)	Total nitrogen (g/kg)	Phosphorus (g/kg)	Potassium (g/kg)	pH	Soil bulk density (g/cm ³)	Soil full field Water content (%)	Soil Thickness (cm)	Slope gradient
A	53.1	2.5	1.15	22.8	5.5-6.8	1.25	30	55	<2°
B	49.1	2.3	1.16	21.2	5.6-7.0	1.35	20	50	2-5.8°

3. DATA AND METHODS

3.1 Data acquisition

We used GPS and total-station to get enough special information and land use data of area A and B, including: dividing line of different land-use and study areas, contour line with 5m elevation difference, data of 4260 elevation points, data of other facilities, surrounding water area and rural residential area's boundary. (Zhang Xianfeng et al., 2000; Xu Saocuo et al., 1998; Shen Qinghua et al., 2005; Li Yinong et al., 2005) Besides, we also used remote sensing images of the study areas. The images were taken from institute of remote sensing in Chinese academy of sciences, and social economic data were selected from documents and yearbooks.

3.2 Methods

According to “Engineering design of land consolidation” (Chinese Ministry of Land and Resources Centre, 2005), and based on natural and cultivated conditions in study area A and B, we used GIS software, remote sensing image and elevation data for spatial analysis. Then we studied on the impact of simulation by using different methods of land formation on the area to determine the optimal design method of land consolidation.

In this section we introduced an optimized method for land consolidation. For comparison, these following characteristics should be taken into account:

(1) After leveling up by plane method, the field is so flat that it is not good for the subsurface drainage needs of the chernozem arable area. The study areas are gentle slope and hilly plain micro-topography, respectively. Flat land formation of the land consolidation will increase the amount of earthwork; through the undulating terrain in the larger region after finishing the land will have a height differences between the fields, and will bring some inconvenience for the mechanized operations.

(2) After leveling up by slant method, the design slope of field which is exactly consistent with the irrigation direction, can not lead to a slow flow speed, irrigation water (or rain, snow and ice melt water) on the ground after would exacerbate erosion of cultivated land.

(3) Optimized amending local topography method can make the internal field flat, and achieve a high degree of consistence within neighboring field blocks. Considering climate and terrain conditions and farming methods of the study area, amending local topography method would be more appropriate for the chernozem land consolidation. (Fig.3)

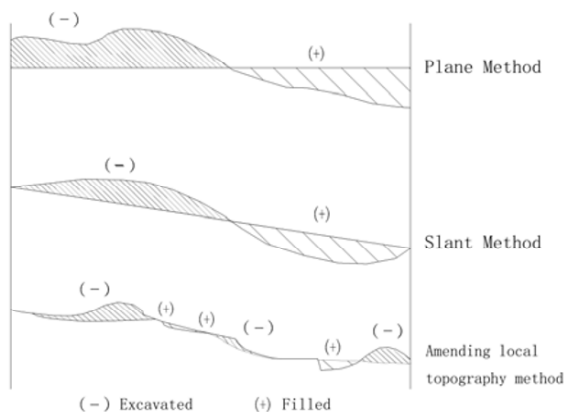


Fig.3. Land Consolidation Methods

4. CULTIVATED LAND FORMATION RESULTS

Most cultivated blocks in our study areas are less gentle slope, the paper mainly selected the A study area more than 3 °and B study area greater than 5 °(mild erosion of soil surface area)([Department of Water and Soil Conservation, 1997](#)). We used the spatial data which were obtained through GPS, field investigation and remote sensing image to map the land use maps of study areas A and B. By using 3D maps, slope charts and the 20 × 20m DEM (Digital Elevation Model) (Fig. 4, 5), which were formed by Surfer and ArcGIS, the program of land consolidation earthwork calculation was optimized based on AutoCAD.

The optimization process is as follows: the ArcGIS was used to generate a slope map, determining the region to be consolidated (Fig. 6, 7). In addition, by using the planning maps superimposed with the study area rule grid DEM map as well as the study area slope map, the selecting longitudinal slope maps of planning field blocks (slope too big ups and downs of the regional field blocks) were obtained. Based on the principle of incompletely changing original topography, the excessively concave convex field, according to whole longitudinal slope direction of field blocks, can be drafted. Through filling the lowlands, low-cutting highlands method, longitudinal slope maps of planning field blocks were formatted. And then by filled longitudinal slope surface area and multiply the field blocks width, we measured filling of the earthwork.

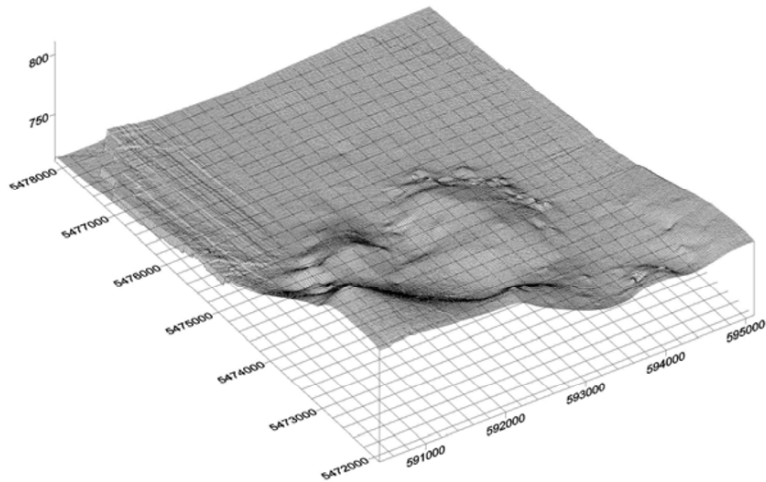


Fig.4. Digital Elevation Model of Study Area A

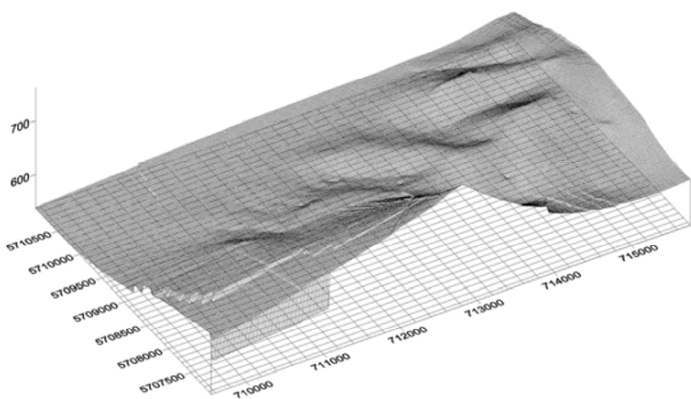


Fig.5. Digital Elevation Model of Study Area B

The result indicated that by using the optimized method, the consolidation works for the earthwork of study area A is 3 532 000m³ and 1 072 000m³ for study area B. Comparing to calculation results by plane methods, the earth volume decreases by 3/4 and 7/8, and for slope method, the reduced earthwork is 1/2 and 1/3. At the same time, to use optimized method can significantly save the earthwork, reducing the risk of decline in the quality of chernozem land, and this decline due to large-scale removal of surface land. Using optimized revision local topography method to amend the layout can reduce partial soil erosion strength, and so that the height difference of planning cultivated land between field blocks can be narrowed, and it is good for mechanized operations and drainage needs.

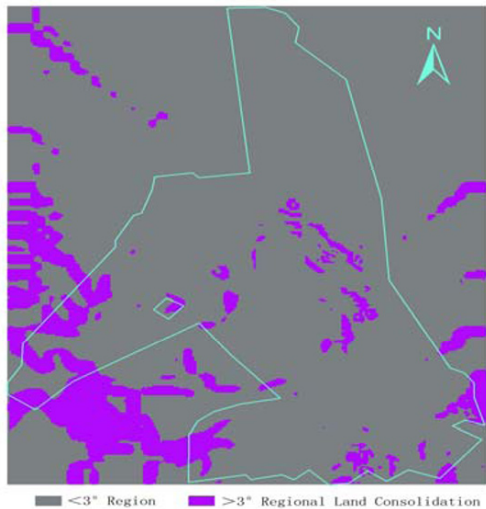


Fig.6. Gradient Map of Study Area A

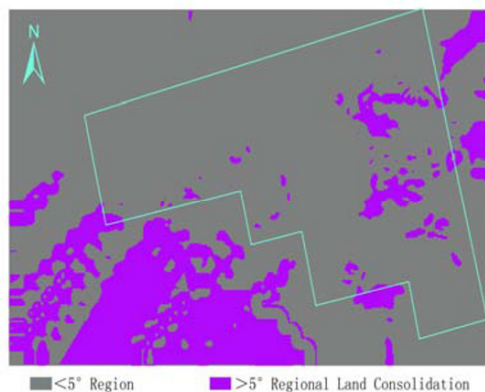


Fig.7. Gradient Map of Study Area B

5. CONCLUSION

In Hulun Buir, two land consolidation regions which have different natural condition and the agricultural tillage methods, application of 3S technology to the land leveling methods has been discussed. We used 3S technology to design land consolidation project and calculated earthwork, and adapt to the local mechanization production method to avoid the soil quality decline and soil erosion caused by large-scale removal of land and site preparation. Also amending local topography method can save the earthwork, and save the investment of land consolidation. It is useful to apply the method land consolidation to extend chernozem region of China.

So we suggest the method of amending local topography. The conclusion is expected to provide the effective method and the suggestions for land consolidation of the chernozem area.

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SIMULATION DESIGN OF THE SPIRAL GROOVE PRECISION SEED-METERING DEVICE FOR SMALL GRAINS

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Abstract: At present, most of small grain crops such as millet and forage seeds are sown by external force feed in mainland China, which has some problems of wasting seeds, uneven seed distribution and so on. Therefore, it is needed to design a precise feed device for small grain crops. The author's of this paper established a three-dimensional model to design the spiral groove precision seed-metering device using Pro/Engineer. The movement simulation and clearance were tested between the seeding roller and the shell by mechanism module. According to the analysis results, the defaults of the feed device were modified, so that the model structure was optimized. The simulation results showed that this device is simple and suitable and suitable for the seeding requirements of small grains.

Keywords: seed-metering device, small grain crops, simulation design

1. INTRODUCTION

The fluted-roller metering system invented by Jethro Tull has been used on grain drills for over 300 years (Brown E, 2003). The system is a model of simplicity and has been sufficient for seeding small grains. Based on this system, the seed-metering device and the relevant technique have been

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greatly improved and developed. But this traditional seed-metering device is still unable to implement precision seeding for small grain crops. The scholars all over the world have devoted themselves to develop a precision small grain crops seeding devices, which has better and better seeding accuracy to save seeds and improve the following cultivation work.

The study of seed-metering device for small grain crops began in the 1960s abroad. A very successful vacuum seeder for precision sowing of fine seeds was invented in 1967 (Gianini et al, 1967). A vacuum metering system was used for sowing cotton in 1970 (Hudspeth et al, 1970). A punch planter was designed and constructed for sugar beet using a wheel with six conical punches on the circumference (Jafari et al 1972). Fluid meter for cotton and sorghum were studied and the seeding efficiency was determined. (Lepori 1972). However, they did not investigate the seed metering uniformity of the system. The operational characteristics of the fluted-roller meter of a grain drill was designed (Jafari, 1991), he noticed the seed metering uniformity is impaired by the sudden release of the seed batches, especially at higher rates. To overcome this shortcoming, he considered to use multi-flight screws in a metering device for better uniformity.

Many practical progresses have been made in the research of precision seeding for corn wheat and other crops in China and some models have been manufactured for farmers. The study of precision seeding for small grains such as millet and forage has been started, however, the reliable machines are rarely seen. The millet and other small grain crops are mainly planted in the hilly areas of Shanxi Province China, which are the national production base. At present, most of small grain crops are sowed by manpower and animal power. This kind of traditional manual work is very difficult, consuming time and wasting seeds. The study of planting technology and equipment for small grain crops has been become an important and urgent program.

2. THE DESIGN OF SPIRAL GROOVE SEED-METERING DEVICE

Special-shaped spiral groove precision seed-metering device used for small grain crops is designed. The key point is to use cylindrical seeding roller with multi-head spiral grooves. The roller is housed and can not move along its axis. Seeds fall into the space orderly by gravity, and then seeds grouped in a line along the spiral grooves. Seeds move forward to the outlet of the metering system then fall into the tube.

2.1 The size and shape of spiral grooves

The design concept of the spiral groove section is that: the cross section of the groove can accommodate only one seed and self-locking must be avoided between seeds. For different shape grains, comparative analysis of several section structures are as follows:

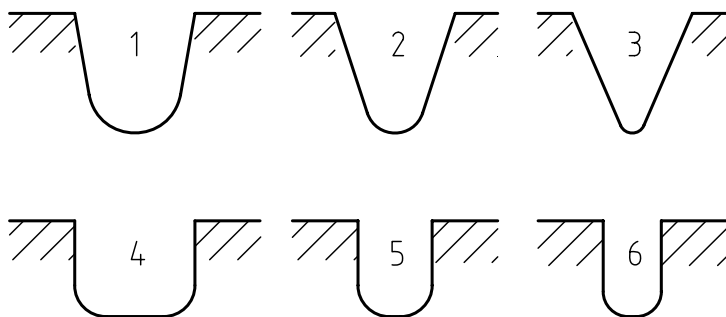


Fig.1: The structure of the spiral groove sections

The structure of the spiral groove sections are illustrated in Fig. 1. No.1, 2, 3 are the V-shaped sections, No.4, 5, 6 are the rectangular sections. In order to avoid the self-locking in the spiral groove, the circular cornering is designed in the spiral groove bottom.

The width of the rectangular shape is larger to accommodate more seeds, so that higher friction exists among seeds. This situation may result in self-locking even blocking while the seeding roller is working. The V-shaped bottom is smaller than that of the rectangular. The friction is much lower among seeds, so the self-locking can be reduced efficiently. This type of bottom is stable for seeding performance. Therefore, the V-shaped bottom is chosen in the design; the size of spiral groove sections can be designed for different crops.

2.2 The inclination and numbers of spiral grooves

The diameter of the roller and the pitch of the spiral groove are selected as 50mm and 32mm respectively. In this condition, the inclination meets demand. Seeds can complete axial movement.

Spiral groove number influence the seeding uniformity. We increase the numbers to improve it. The spiral groove seeding roller, which spiral number is 3, is shown in [Fig. 2](#).

2.3 The design and calculation of the shell

It is important to design the size of inlet , outlet and the internal diameter of the shell. Based on the measured values of material physical characteristics, the key points are: (1) when the corner angle of the inlet gate is 90° , it is good for falling seeds, (2) the rectangular inlet can improve the ability of filling and separating seeds, (3) the axial distance between inlet and outlet is two thirds of the pitch. The width of outlet is designed as 10mm. In order to facilitate the seed-filling, an adjustable flap is installed on the inlet. The shell 3D model is shown in [Fig. 3](#).

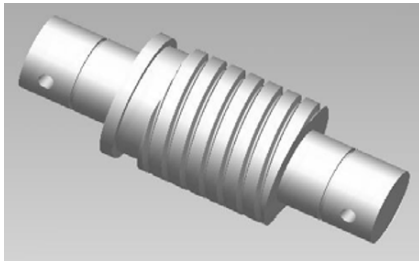


Fig.2. The spiral groove seeding shaft

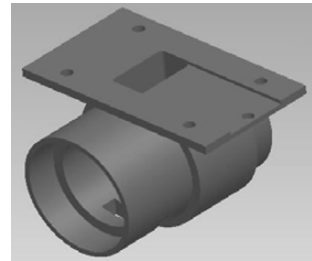


Fig.3. The seed-metering device shell

3. THE ASSEMBLY AND SIMULATION OF SEED-METERING DEVICE MODEL

3.1 The assembly of device model

The spiral groove precision seed-metering device is made of the seeding roller, the shell and the hopper. The assembly process is (1) fix the shell in the assembly, and choose the connect type between the shell and the seeding roller by Pin, (2) place hopper, bolts and nuts with constraints of Align and Mate, (3) assemble axletrees and snap rings with fully constrained, then complete the assembled model. The explode view of spiral groove seed-metering device model is illustrated in [Fig. 4](#).

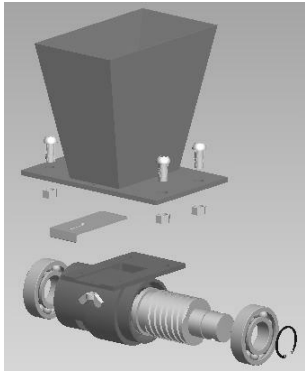


Fig.4 The explode view of seed-metering device

3.2 The simulation and analysis of roller model

When the assembly is completed, we enter the Mechanism module: (1) flip the axis of the seeding roller as a new servo motor and define rotary speed, (2) choose kinematics as an analysis type, define length and rate in the graphical display window and run the analysis, (3) drag the playback button to observe the situation of kinematical pairs, (4) click mode button to check global interference among components, (5) generate analysis graphics of measure results and optimize parameters. By monitoring, there is no interference among all components. The movement simulation analysis is shown in Fig. 5.

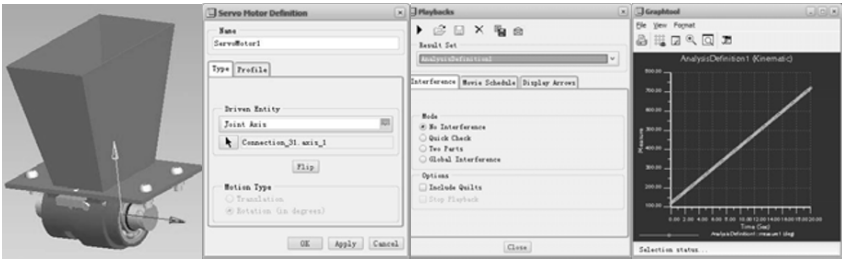


Fig.5 The movement simulation analysis

4. CONCLUSION

Based on Pro/E, the 3D modeling and movement simulation of spiral groove precision seed-metering device for small grain crops is processed and

analyzed. The results showed that components have no interference; the structural design is reasonable. Refer to dynamics question, as moisture, maturity and geometrical shape of seeds and other organisms are uncertain, it is hard to get reliable results from simulation. Therefore, tests and multiple experiments of prototypes are necessary steps. Based on the simulation results and drawings of this study, sample machine is being constructed. Primary test of the sample machine indicated that the simulation designing was reliable.

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DEM-BASED STUDY OF HABITAT CHARACTERISTICS OF TORREYA FENGQIAO IN KUAJI MOUNTAIN, CHINA

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Abstract: The habitat characteristics of *Torreya* were investigated based on high resolution DEM and remote sensing image. The distribution of *Torreya* was mapped by visual interpretation of IKONOS image. The landform and PCA analysis results showed that curvature, altitude, aspect and slope were found to be the dominant features controlling spatial distribution pattern of *Torreya*. A certain degree moisture related variables were proved to be the most important parameters to explain *Torreya* habitats preferences. The preferable habitat requirement for *Torreya* focused on those concave and southwest hillsides with elevation between 400 and 600 m and slope less than 30°.

Keywords: vegetation distribution, digital elevation model, landform analysis, GIS

1. INTRODUCTION

Accurately understanding the native habitat for rare plants with restricted geographic distributions is an important component of plant conservation and development planning. Remotely sensed data have been widely used for assisting in vegetation mapping in the last few years and have been proved an effective tool. They offer the possibility of extrapolating mapping results,

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especially in large and hardly accessible remote areas (Kalliola and Syrjänen, 1991). Meantime, topographical attributes derived from Digital Elevation Model (DEM) are widely used in mountain ecology (Moore et al. 1991; Hoersch et al., 2002; Garcia et al., 2007), offering a much more reliable predictor database compared with direct climatic or edaphic site factors (Davis and Goetz, 1990). These works have served to the understanding of the complex interactions between spatial distribution patterns of site factors and vegetation types. However, compared to common species, the endemic and rare plants with a narrow size distribution showed quite different in habitat selection. It is challenging, due to lack of information synthesis on the ecology of rare plants, lack of spatial data for relevant environmental attributes and scales. And there have been few studies of analysing preference habitat for rare species based on the level of species (Claessens et al., 2006, Tatsuhara and Antatsu, 2007). Fortunately, with the recent development of high resolution IKONOS or QUICKBIRD remote sensing images and DEMs, it provides a new opportunity to make a thorough analysis to the site selection and distribution patterns of rare species.

Torreya Fengqiao (*Torreya grandis* var. *Merrillii*), an evergreen conifer in genus *Torreya* of family *Taxaceae*, is famous for its precious rare nut in China (Li Zhangju et al., 2005). Researches relating to its distribution and habitat requirements have been carried out for the last decades including biological characteristics (Ren Qinliang, 1989), suitability of introduction and cultivation (Liu Quan et al., 1993), climatic requirements (Fu Yulu et al., 1999) and spatial distribution (Meng Hongfei et al., 2003). However, our knowledge about interactions of its distribution and environmental factors is rather poor (Han Ninglin et al., 2006). In the present study, a combination of DEM, remotely sensed image and field data were used to find a statistical correlation with the spatial distribution pattern of *Torreya Fengqiao*. The major objective of this study was to find the habitat characteristics of *Torreya Fengqiao* in Kuaiji Mountains for its sustainable development.

2. STUDY AREA AND METHOD

2.1 Study area

The study area, Kuaiji Mountains, is located at northeastern Zhejiang province, East China (Fig. 1). The orientation of mountain is from southwest to northeast. Its length is 90 km from south to north and the width was 30 km from east to west. The core zone of *Torreya Fengqiao* is located in Zhaojia town, Zhuji County (121°29'–121°33' E, 29°40'–29°44' N), lying in the

middle part of the Kuaiji Mountains and covering an area of 27 km², Elevation ranges from 90 to 830 m above sea level. The climate is characterized as subtropical monsoon zone. More than 28,000 ancient trees (about 200 to 600 years old), with trunks up to 2.0 meters in diameter and heights up to 15 meters, still survive in the wild in this area (Meng Hongfei et al., 2003).

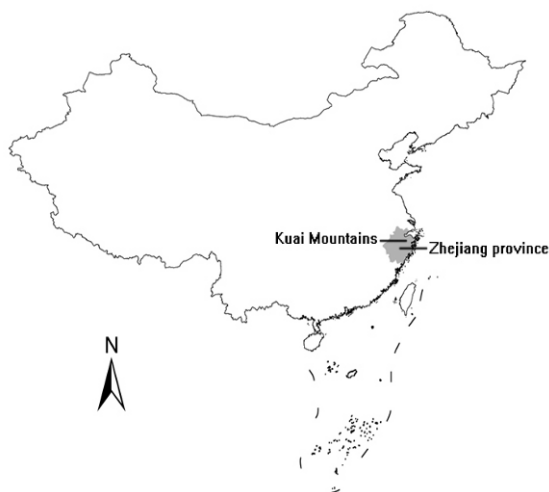


Fig.1. The location of Kuaiji Mountains in Zhejiang province, China.

2.2 Data and data preparation

2.2.1 DEM data

The DEM data was derived from the topographic maps at the scale of 1:10,000 using the software of ArcGIS 9.2. The contours were firstly digitized, then the linear map was used to build TIN, and at last, the DEM with 10 m resolution was produced. Several topographical variables such as elevation, slope, aspect, curvature, hillshade and topographically derived variables (wetness index, sinaspect and cosaspect) were used as possible environment related explanatory variables to describe habitat of *Torreya Fengqiao*. The respective variable grid layer was computed from the 10-m spatial resolution DEM and ArcGIS software. For more details about the landform parameters see Hoersch et al. (2002).

2.2.2 Remotely sensed data

IKONOS image was fused using an PANSHARP transformation, then orthorectified based on a 1:10,000 digital topographic map, a Digital Elevation Model and PCI Orthobase software, resulting in fused image with spatial resolution of 1 m (PCI Geomatics, 1998). Considering the complicated features of forest cover in study area, different ways were tried to improve the accuracy of classification, and visual interpretation was finally used for *Torreya* mapping. An example of recognition for *Torreya* Fengqiao trees extraction was showed in Fig. 2. A total of 215 patches of *Torreya* were identified.. *Torreya* trees were classified rather well and the classification accuracy based on 56 validation points amounted to 89.6% with 8% standard deviation. Inaccuracies were caused by those scattered *Torreya* trees with little crown among other type of dense forests.

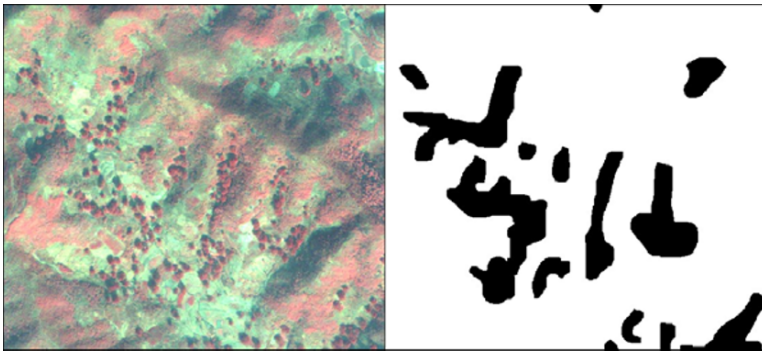


Fig. 2. Pattern recognition for Torreya extraction: IKONOS image (left) and resulting (right)

2.3 Methods

Firstly, *Torreya* distribution patches and ten grid layers of environmental variables was generated based on IKONOS image and DEM data. Then the analysis of correlation between the spatial distribution of *Torreya* Fengqiao and its site characteristics with the grade data of environmental variables was performed in GIS for Finally, quantitative analysis was carried out with the help of Social Professional Statistics Software (SPSS) for Principal Components Analysis (Hoersch et al., 2002).

3. RESULTS AND DISCUSSION

3.1 Relationship between topography and spatial distribution of *Torreya*

The relationship between spatial distribution of *Torreya Fengqiao* and the characteristics of landform are described in Table 1. Topographical parameters such as curvature, elevation, slope, and aspect seems having high correlation with its distribution and they appear to be very useful in explaining the occurrence, distribution and abundance of *Torreya Fengqiao*. It showed that the preferable habitat requirement for *Torreya Fengqiao* focused on those concave and southwest areas with elevation between 400 and 600m and slope less than 30°.

Table 1. Habitat characteristics of *Torreya Fengqiao* in Kuaiji Mountains

Variable	Classes	Percent	Description
curvature	> 0	36.13	Convex shape
	= 0	0.72	Flat
	< 0	63.15	Concave shape
DEM	1	20.49	<400 m
	2	76.14	400—600 m
	3	3.36	>600 m
aspect	1	22.64	0-90°
	2	24.18	90-180°
	3	32.51	180-270°
	4	20.49	270-360°
	5	0.17	Flat
sinaspect	< 0	53.17	West slope
	= 0	0.02	Flat
	> 0	46.82	East slope
cosaspect	> 0	43.31	North slope
	= 0	0.01	Flat
	< 0	56.68	South slope
slope	1	2.80	<10°
	2	20.52	10—20°
	3	43.98	20—30°
	4	32.70	>30°

According to fieldwork, different elevation region in Kuaiji Mountains showed important difference in spatial pattern due to their various site factors. In lower elevation areas, it only located along the narrow streams and adjacent slopes which could afford a moist and cool habitat. So, only a little proportion (20.49%) survived in this zone. However, 76.14% of it was

located between 400-600 m in elevation. Mature trees in this area are thriving in open, sunny and exposed locations. It seems to be a relatively dry microsite, but more than 60% are on locally concave topography and mid to lower slopes in order to keep with steady soil moisture. Elevation condition is recognized as an important mechanism for its occurrence, because it has been able to altitudinally compensate for rises in temperature during summer dryness.

3.2 Principal components analysis

Results of the PCA using the whole data set are shown in Table 2. About 5 principal components explain over 80% of the 10 landform features. The first component represented curvature relating somehow to a certain soil moisture requirement. The second is a combination of aspect and hillshade representing solar radiation and soil moisture. The third component was highly correlated with elevation. This partly supported the results of topography analysis (Table. 1) which meant *Torreya* species exhibited high selectivity of elevation belt. And the last two components stressed the meaning of slope and aspect for *Torreya* which also had great correlation with soil moisture and solar radiation. Therefore, it could be concluded that a certain range of curvature on distinct aspects and altitudinal belt are important for *Torreya*. Since most of major influencing factors had strong correlation with soil moisture, it suggested that a certain degree moisture related variables proved to be important parameters to explain *Torreya* habitats preferences.

Table 2. Cumulative eigenvalues and Eigenmatrix for the overall Principal Component Analysis (PCA)

PCA	Cumulative variance	Parameter	Component				
			1	2	3	4	5
1	25.14	DEM	.366	-.007	.905	-.171	.003
2	46.57	aspect	.046	.805	-.084	-.347	-.279
3	64.00	sinaspect	-.018	-.883	.054	.234	.272
4	78.36	cosaspect	-.065	.358	.163	.630	.643
5	88.63	slope	.188	-.005	-.295	-.660	.500
6	93.845	wetness	-.581	-.011	.167	.496	-.435
7	97.02	curvature	.928	.000	-.211	.270	-.128
8	99.27	plancurve	.801	.000	-.254	.167	-.004
9	99.71	procurve	-.786	.000	.114	-.286	.203
10	100	hillshade	-.033	.896	.078	.289	.259

For the biological characteristics of *Torreya Fengqiao*, several important periods during growth and development stage such as miosis of floral organ, anthesis, pollination and fruit ripeness have many affinities with moisture condition. The shallow roots of the species further exacerbate its

vulnerability to water deficits especially in the period of high temperature and dryness in summer (Ren Qinliang, 1984; Wu Jungen et al., 1994; Han Ninglin et al., 2006). The growth patterns and site-selectivity were consistent with the moisture preferences of *Torreya* species.

4. CONCLUSION

Environmental factors have been considered as the main determinant in vegetation distribution (Leduc et al., 1992). *Torreya Fengqiao* has presumably survived from countless natural disaster in its native habitat for millennia; this suggests that the current spatial distribution pattern is most suitable for its growth. Based on high resolution DEM and IKONOS image, some basic rules of spatial distribution of *Torreya Fengqiao* are proposed. Curvature, altitude, aspect and slope were found to be the dominant features controlling spatial pattern of *Torreya Fengqiao* in study area. The study concludes that the occurrence of *Torreya Fengqiao* in this region largely concentrates on those concave and southwest hillsides with slope lower than 30° and elevation belt between 400 and 600m. The results suggest that a certain degree moisture related variables proved to be the most important parameters to explain its habitats preferences. Understanding relationships between environmental variables and spatial distribution of *Torreya Fengqiao* in this area helps us to apply these findings in management, reclamation, and development of *Torreya* plantation.

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QUANTITATIVELY OPTIMIZED SELECTION OF PROPER SCALE IN LAND USE CARTOGRAPHIC GENERALIZATION

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Abstract: This paper quantitatively analyzes the map information of different scales in the range of the mapping scale by making use of landscape pattern index, and constructs an evaluation index system by the standard of cartographic generalization evaluation. It takes land use cartographic generalization in Da Xing agricultural region of Beijing for an example, evaluates on the map quality between the scale interval of 10 thousand and 100 thousand, and selects the appropriate scale so as to meet the need of land use cartographic generalization.

Keywords: scale interval, quantitatively analysis, evaluation index system, landscape pattern index, map quality

1. INTRODUCTION

Spatial data has a quality of multi-scale, many scholars have mentioned how to select proper scale to express geographical object in cartographic generalization and graphic display (Tate N et al., 2001; Sheppard E et al., 2004; WANG Jia-yao et al., 2004; AI Ting-hua et al., 2005; Li Zhi-lin, 2005). In the quantitative researches of cartographic generalization, many of them aim at given the integrated index of mapping and visible standard. And they will evaluate on many aspects; the precision, position and figure of spatial data, map load, map tidiness and changes of semantic information (Dijk, S.F. van,

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et al,2002; Longin jan Latecki et al.,2000; Philip N Klein et al, 2001; Sylvain Bard,2002; Zhilin Li et al.,2002; WANG Qing-guo,2006; ZHANG Fa, 2006),but all of these are short of scale rules of map the strict corresponding relations of particular scales. Thus, it is very necessary to have a discussion on the best scale expression of map information, that is to say that we should discuss on the selection of the most appropriate scale that can meet the needs of cartographic generalization evaluation standard.

Categorical map cartographic generalization has become a hot point, following topographic map cartographic generalization. Martin Galanda(2003),Moritz Neun and Stefan Steiniger(2005)brought forward a series of technique levels from microcosmic and medium perspective in researches of topographic map cartographic generalization, but the evaluation level emphasized particularly on map restriction. Nevertheless, solely depending on the microcosmic and using the medium perspective in researches and having no guidance of macroscopic law in mapping information, it is impossible to choose a proper threshold which can engender restriction.

Land use data is a typical type of polygon categorical map , it is fully covering, non-overlapping and seamless. In the aspect of semantic information, this kind of data is hierarchical (Bader M et al., 1997).Land use data cartographic generalization is to develop rules of cartographic generalization so that it can express the data mining process of the information of land use which has a particular scale. And the expressed land use information is decorated though some vision means such as exaggeration and position change on the basis of data scale rules. Thus, scale rules of land use data is the background of cartographic generalization. The adjustment of visible expressions needs to be based on the macroscopic rules. In order to reflect scale rules of land use data, the research should be started followed by three steps. First step is to study the changes of mapping information of the main land category after cartographic generalization, in the background of space pattern of them which has important semantic significance. The second step is to select the most appropriate scale to express land use information on the map by making use of evaluation index system constructed by using the principle of cartographic generalization evaluation.The third step is to make visible adjustment of map information to meet the need of visible and tidiness.The second step is the research point of this paper.

2. RESEARCH APPROACH

The author evaluates the pattern index of series scale maps in mapping scales so as to select the most appropriate scale to express the information

onthe map. Specifically, this paper on the basis of the integration of the database and the rules of cartographic generalization, integrates the area polygons of the main type of used land and forms the series scale map in research scope. And this paper builds an evaluation index system by quantitatively analyzing the map information of area polygon by using the landscape pattern index, and chooses a scale which can best meet the need of mapping from series scale maps.

3. SELECTION OF LANDSCAPE PATTERN INDEX

The evaluation index of land use cartographic generalization traditionally used principles to take place of quantitative standards. In researches of cartographic generalization, the mapping information of area polygons is measured by means of landscape pattern index measurement. No matter what kind of the index is, it can be changed or directly cited from landscape pattern index (Bjørke,1996,2001;Beat Peter, 2001). Stefan Steiniger and Robert Weibel(2005)pointed out, the majority of statistic and the measurement of density relation in field of cartographic generalization came from landscape ecology index.

According to principles of land use cartographic generalization evaluation, we can make a connection to landscape pattern index, and construct a mapping information evaluation system of land use cartographic generalization. As shown in Table 1, we choose indices which can reflect area changes, quantity changes, shape rule degree and geometrical complexity degree of different land types as those of mapping information quality evaluation in mapping scale.

Table 1 The index system for scale change

Types of index	Names of index	Explanation
Area index	Percentage of Landscape(PLAND)	Changes of land type area proportion in experimental area
Density index	Polygon Density(PD)	Quantity changes of land
Shape index	Area Weighted Mean Shape Index(AWMSI)	Reflecting the global shape regularity of one type of land
Fractal dimension index	Area Weighted Mean Fractal Dimension (AWMPFD)	Reflecting the geometrical complexity degree of one land type

These indices put more emphases on ecological significant in the study of landscape ecology. But here, these indices emphasized particularly on reflecting changes of mapping information in cartographic generalization

mapping scale. Among them, PLAND means information quantity changes of all land types, in evaluation index it reflects the differences between the present area of all kinds of land and the primary area of them after integration; PD reflects changes of the quantity of polygons, the distribution of it and integrated compression ratio of data in cartographic generalization; Shape index reflects changes of polygon regularity in cartographic generalization; Fractal dimension index reflects the geometrical complexity degree changes of figures in cartographic generalization. In this research, shape index and area index take area weighted mean measurement to reflect the changing rules of global mapping information.

The selected index calculation formulae are shown as the following (1)~(4).

$$\text{Polygon Density: } PD_i = N_i * 100 / A \quad (1)$$

$$\text{PLAND}(P_i) = \sum_{j=1}^n B_{ij} / A * 100\% \quad (2)$$

$$\text{AWMSI} = \sum_{i=1}^m \sum_{j=1}^n \left[\left(\frac{0.25 P_{ij}}{\sqrt{B_{ij}}} \right) \left(\frac{B_{ij}}{A} \right) \right] \quad (3)$$

$$\text{AWMPFD} = \sum_{i=1}^m \sum_{j=1}^n \left[\left(\frac{2 \ln(0.25 B_{ij})}{\ln(B_{ij})} \right) \left(\frac{B_{ij}}{A} \right) \right] \quad (4)$$

In these formulae: PD_i is the average number of the i^{th} land type polygons in every 100 hm^2 of experimental area, $PD > 0$ and no upper limit. N_i is the number of i^{th} land type polygons. A is the total area of all types of lands in the experimental area. $\text{PLAND}(P_i)$ is the percentage of landscape of the i^{th} land type in experimental area. B_{ij} is area of the j^{th} polygon of the i^{th} land type. n is the number of i^{th} land type polygons. AWMSI , no upper limit. AWMSI becomes bigger with the increase of polygon shape's irregularity; When the polygons are all squares, $\text{AWMSI} = 1$. m is the number of land types. 0.25 is square emendation constant. AWMPFD is the weighted mean of a single polygon's fractal dimension, and $1 \leq \text{AWMPFD} \leq 2$.

In this study, the mapping information changes degree in mapping scale reflected by the indices mentioned before can be divided into two levels: the land type and the experimental area, corresponding to type level and the mosaic structure of the lands level in study of ecological pattern. In experimental area level, changing rules of mapping information can be synthetically reflected. The change on this level is the important point in this research.

4. THE CONSTRUCTION OF EVALUATION INDEX SYSTEM

Quality of mapping information in cartographic generalization is determined by proportion of land type area, polygon density, shape index and fractal dimension index. Different index occupies different position in this research and the weighting factor reflects the status of them. And all of these indices should be evaluated with quantitative methods. In this paper, we evaluated by using extreme value. It is to mark the best index with 100 scores, the worst one with 0, and the mean ones are obtained by means of linear interpolation.

Thus, we construct a map quality evaluation system by making use of the four indices and $\alpha_1, \alpha_2, \alpha_3$ and α_4 standing for their weights. These weighing values are made with Delphi Model, $\alpha_1=0.4, \alpha_2=0.4, \alpha_3=0.1, \alpha_4=0.1$. Map quality VALUE(X) can be calculated in formula (5).

$$\text{VALUE}(X)=\alpha_1*\text{VALUE}(\text{PD})+\alpha_2*\text{VALUE}(\text{PLAND})+\alpha_3*\text{VALUE}(\text{AWMSI})+\alpha_4*\text{VALUE}(\text{AWMPFD}) \quad (5)$$

5. EXPERIMENT

5.1 The experimental area

Da Xing agricultural region of Beijing is the research region, the traffic and waters land type take 2% of the total area. Because of its relatively simple land use pattern, the cartographic generalization majors in combination and integration and the polymerization operation, displacement and exaggeration are fewer in this research. All of these give prominence to the leading role of macroscopic rules in mapping information scale.

5.2 The classification and the statistic of lands

According to current three grades of lands classification system, in cartographic generalization many of the third type of lands are faced with problems such as deletion and transitional consumption, and in the statistic of pattern indices there are many differences; at the same time, if we use this system directly, in the process of database integration, the combination of many land blocks will engender excessive deletion of information about and use. In this research, we choose 1:10,000 land use data in 2004 of the experimental area as the experimental data, and the three types classification

system in transitional period as the classification system. On the basis of the experimental proposes and the land use features in this area, we take measures of three types classification, the corresponding code of land type is the third grade. We consider the original fourth land type code as the third one, or we combine the lower one to the higher one. Because the span of the scale experiment is long, in order to avoid the influences on the experimental area analysis by the disappearance of some land types which take up low area proportion, we take statistic measures which are similar to the original 8 type's classification system. The advantage is that it can avoid the excessive outburst of the experimental area's individuality and the decrease of its representativeness. Meantime, 8 type's classification can have semantic functions on the integration of small area polygon. The three grades classification can help maintain these qualities such as large quantity of land blocks and complicated relations of land use cartographic generalization.

5.3 The application of semantic significance

In this research, the grades of land types based on their importance levels are: cultivated lands, habitations, industrial and mining sites, garden plots, forest lands, grassplots, unutilized lands.

5.4 The selection of operators in cartographic generalization

To operated factors, the important ground objects can be exaggerated and displaced when their area is less than their mapping area, and it can be maintained and not canceled. To those important ground objects, the area proportion of them is less than 3%. Thus, we omit the method of exaggeration and displacement and use combination and polymerization in cartographic generalization.

5.5 The determination of integrated threshold

According to Beijing Land Use Present Situation Investigation Implementing Regulations ([Beijing Bureau of Land Resources,1984](#)) and Land Use Updating Investigation Technical Stipulation ([Ministry of Land and Resources,2005](#)), the areas of the minimum polygons of land type drawing mapping are:habitations 4.0mm^2 ,cultivated lands, garden plots, and waters 6.0mm^2 ,forest lands, grassplots, unutilized lands 15.0mm^2 . On the basis of the regulations and the knowledge of scale and visual effects, we can make out the experimental standards and get the minimum mapping area and the minimum distance of polygons, as [Table 2](#) show.

Table.2 The minimum of area and distance in map generalization

No.	Scale Denom inator (10 ⁻⁴)	Habitations (m ²)	Cultivated Lands,Garde Plots, Waters (m ²)	Forest Lands, Grassplots, Unutilized Lands (m ²)	The Minimum Distance of Polygons (10m)
1	1	400	600	1500	1
2	1.4	560	840	2100	1.4
3	1.8	720	1080	2700	1.8
4	2.2	880	1320	3300	2.2
5	2.6	1040	1560	3900	2.6
6	3	1200	1800	4500	3
7	3.4	1360	2040	5100	3.4
8	3.8	1520	2280	5700	3.8
9	4.2	1680	2520	6300	4.2
10	4.6	1840	2760	6900	4.6
11	5	2000	3000	7500	5
12	5.4	2160	3240	8100	5.4
13	5.8	2320	3480	8700	5.8
14	6.2	2480	3720	9300	6.2
15	6.6	2640	3960	9900	6.6
16	7	2800	4200	10500	7
17	7.4	2960	4440	11100	7.4
18	7.8	3120	4680	11700	7.8
19	8.2	3280	4920	12300	8.2
20	8.6	3440	5160	12900	8.6
21	9	3600	5400	13500	9
22	9.4	3760	5640	14100	9.4
23	9.8	3920	5880	14700	9.8
24	10.2	4080	6120	15300	10.2

5.6 Results of the experiment

Based on the calculation of model and data process, the mapping quality evaluation scores in the scale of 1:10,000 to 1:100,000 can be obtained, as shown in Table 3.

6. Analysis and Discussion

It is feasible that quantitatively analysis of the map information by making use of landscape pattern index. Through the model, the evaluation scores can be offer. According to the curve of scores, there are some significant turning points whose amplitude is not high, as [Figure 1](#) shows.

Table.3 The scores of mapping quality evaluation

No.	Scale Denominator (10^{-4})	PD Score	PLAND Score	AWMSI score	AWMDFD score	Mapping score
1	1	0	92.50	0	100	47.00
2	1.4	26.04	38.07	42.86	83.33	38.26
3	1.8	28.47	37.92	57.14	83.33	40.60
4	2.2	31.17	37.01	57.14	83.33	41.32
5	2.6	32.79	37.12	57.14	83.33	42.01
6	3	37.57	36.99	42.86	66.67	40.77
7	3.4	39.91	36.33	57.14	66.67	42.88
8	3.8	42.70	44.34	57.14	66.67	47.20
9	4.2	35.23	52.13	57.14	66.67	47.32
10	4.6	35.23	45.89	57.14	66.67	44.83
11	5	52.16	44.321	42.86	66.67	49.55
12	5.4	57.30	42.52	57.14	66.67	52.31
13	5.8	61.261	43.04	57.14	66.67	54.10
14	6.2	65.59	43.53	71.43	66.67	57.46
15	6.6	71.08	42.77	85.71	66.67	60.78
16	7	73.51	38.02	85.71	66.67	59.85
17	7.4	77.84	31.89	100	50	58.89
18	7.8	77.84	31.89	100	50	58.89
19	8.2	84.14	24.09	85.71	33.33	55.20
20	8.6	87.30	19.38	57.14	16.67	50.05
21	9	91.71	17.29	71.43	0	50.74
22	9.4	98.02	13.70	42.86	0	48.97
23	9.8	100	13.84	42.86	0	49.82
24	10.2	100	13.84	42.86	0	49.82

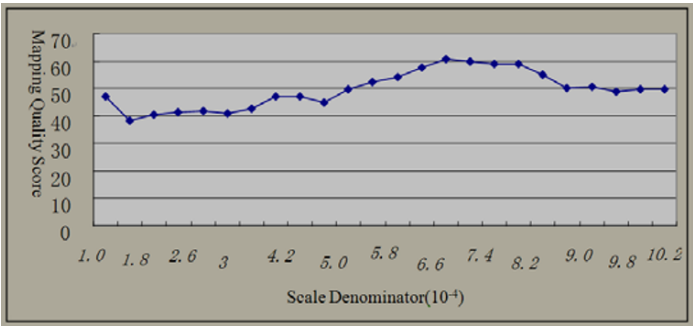


Figure 2 The curve of mapping quality evaluation score

These anomalous points are related to the scale rules of land use data and modeling. According to the distribution of curve, the mapping information in the scale of 1:66,000 is the best. Linking to the dimension chart, integrating all index scores, there is an obvious turning point in the scale of 1:66000, which can indicate the reasonableness of selecting this point.

This experiment proves it can help select an appropriate mapping scale so as to meet the needs of cartographic generalization through constructing an evaluation index system by the standard of cartographic generalization evaluation. This method can provide cartographic generalization with a big rudiment. Based on it, important ground objects can be exaggerated and displaced according to requirements and vision needs.

Certainly, two items should be considered; the first one is the method of indices weighted value and interpolation; the second one is the complexity and uncertainty of scale rules. Besides, the interpolation between the minimum and maximum is linear, but there are some complicated nonlinear relations of mapping information in cartographic generalization. Thus, it is worth to be studied one step further.

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APPLICATION OF GENETIC ALGORITHM IN THE MODELING OF LEAF CHLOROPHYLL LEVEL BASED ON VIS/NIR REFLECTION SPECTROSCOPY

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Abstract: In order to detect leaf chlorophyll level nondestructively and instantly, VIS/NIR reflection spectroscopy technique was examined. In the test, 70 leaf samples were collected for model calibration and another 50 for model verification. Each leaf sample was optically measured by USB4000, a modular spectrometer. By the observation of spectral curves, the spectral range between 650nm and 750nm was found significant for mathematic modeling of leaf chlorophyll level. SPAD-502 meter was used for chemometrical measurement of leaf chlorophyll value. In the test, it was found necessary to put leaf thickness into consideration. The procedure of shaping the prediction model is as follows: First, leaf chlorophyll level prediction equation was created with uncertain parameters. Second, a genetic algorithm was programmed by Visual Basic 6.0 for parameter optimization. As the result of the calculation, the optimal spectral range was narrowed within 683.24nm and 733.91nm. Compared with the $R^2=0.2309$ for calibration set and $R^2=0.5675$ for verification set without concerns of leaf thickness, the effect of leaf thickness on the spectral modeling is significant: the R^2 of calibration set and verification set has been improved as high as 0.8658 and 0.9161 respectively. The test showed that it is practical to use VIS/NIR reflection spectrometer for the quantitative determination of leaf chlorophyll level.

Keywords: leaf chlorophyll level, VIS/NIR reflection spectroscopy, genetic algorithm, leaf thickness

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1. INTRODUCTION

The evaluation of leaf chlorophyll level is essential for farmers to judge the growing conditions of crops they plant. One of convenient ways to detect leaf chlorophyll is to use SPAD chlorophyll meter. SPAD is the short name of Soil Plant Analysis Development. Minolta Camera, Japan, is the well-known manufacturer in the world producing a serial of SPAD meters. Basically, SPAD meter measures the relevant ratio of the absorbance intensities of two bands of red light and near infrared light, and exhibits not the real chlorophyll level but the “greenness degree” of the leaf it detects (Minolta Camera Co. Ltd, 1989). It is also widely used to measure the nitrogen level of plant so as to indirectly help farmers learn about whether the growing crop is lack of nitrogen (Wu et al., 1998; Chang et al., 2003; Lopez-Bellido et al., 2004; Zhu Zheyang et al., 2006; Qiu Zhengjun et al., 2007; Hoel et al., 1998). In this way, the fertilizer can be exactly managed with the purpose of protecting ambient pollution, especially the water sources around. As for remotely monitoring the growth conditions of crops, however, SPAD meter shows its deficiencies, such as mechanical touching with the leave sample, shortage of other measurements like pH, water content, etc. Nowadays, a few of researches have been conducted to use other techniques to detect the growing conditions of plant (Cho et al., 2007; Pinkard et al., 2006; Wu et al., 2007). Thanks to its fast signal detection and advance chemometrical methods, visual and near infrared spectroscopy (Vis/NIRS) becomes one of promising techniques in the field of plant and soil information detection (Zhu Zheyang et al., 2006; Qiu Zhengjun et al., 2007). Bauerle et al. (2004) pointed out that in the spectral range from 400nm to 700nm there existed some links between the readings of SPAD meter and the transmission spectra of leaves. But he also emphasized that no obvious relationship can be established between leaf SPAD measurement and its reflection spectrum. Thus, some effort should be made to explore the problem. In this study, we use fiber-optic OEM modular spectrometer to build the mathematical model of leaf chlorophyll level based on Vis/NIR reflection spectroscopy.

2. MATERIALS AND METHODS

2.1 Leaf samples and instruments

All leaf samples were collected from Agriculture Campus, Zhejiang University, in two periods of time. On January 15, 2008, 50 leaves were

collected and 70 measuring points were selected as the calibration set. On January 25, 2008, another 40 leaves were picked with 50 sample points as the verification set. All leaf samples were water-cleaned and natural air-dried under room temperature of 25°C. Each measuring point is ink-marked by a circle with 1cm diameter and given a sequence number. The circle center is used for measuring point. In the test, a USB4000 fiber-optic OEM modular spectrometer (Ocean Optics, USA), with its spectral range from 346.01nm to 1038.08nm, is used for spectral collection. Its integration time can be adjusted from 3.8ms to 10s. A reflective fiber-optic is vertically fixed about 5cm high above the surface of leaf to be tested. After the spectroscopic measurement, each leaf sample is measured by SPAD-502 meter (Minolta Camera, Japan) for its leaf chlorophyll level. Data processing program is written by Visual Basic 6.0 and spectral curves are drawn in Matlab 7.0 and Microsoft Excel 2003. Leaf thickness is measured by a micrometer (Shanghai Measuring Meter Factory, China) with its precision 0.01mm.

2.2 Spectral data preprocessing

The original reflective spectra of leaf samples are drawn in Fig.1. Dark spectrum refers to the one with illumination light switched off; reference spectrum means the reflective spectrum of illumination light itself. Due to the existence of dark spectrum, each sample spectrum has a deviation. Let $D(\lambda)$, $R(\lambda)$ and $S(\lambda)$ the intensities of dark spectrum, reference spectrum and sample spectrum at wavelength λ . To eliminate the influence of dark spectrum on reference spectrum and sample spectrum, we design spectral reflection rate of sample as follows,

$$REF(\lambda) = \frac{S(\lambda) - D(\lambda)}{R(\lambda) - D(\lambda)} \quad (1)$$

Then, the spectral absorbance rate of sample can be calculated by

$$ABS(\lambda) = -\log_{10}(REF(\lambda)) \quad (2)$$

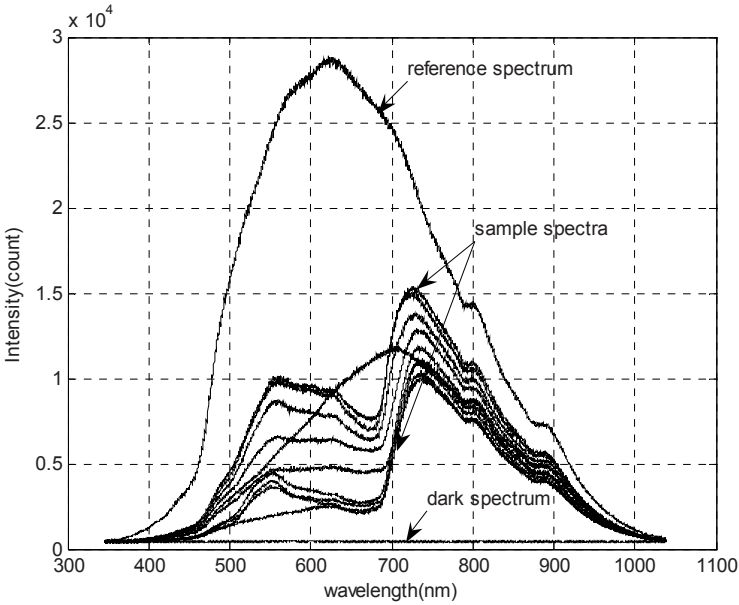


Fig.1: Reflection spectra of several leaf samples

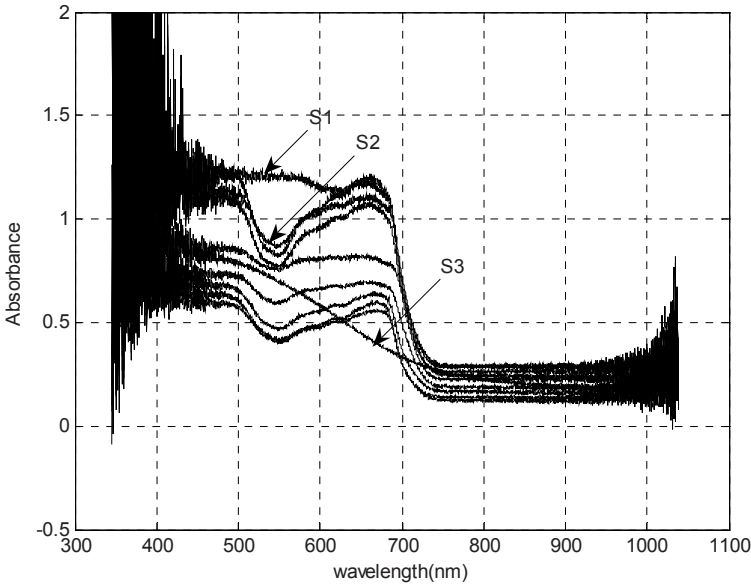


Fig.2: Absorbance spectra of several leaf samples

The result is shown in [Fig.2](#). It is obvious that different leaves or different measuring points on one leaf have distinct light absorbance. A purple leaf

marked by S1 has its SPAD reading of 47.5, another green leaf signed by S2 has the same value. Based on this phenomenon, we found that only the red side from 650nm to 750nm of each absorbance spectra is close to each other. It gives us an idea that the red side of leaf reflection spectrum can be used for mathematic modeling of leaf chlorophyll prediction. The absorbance spectrum of a yellow dried leaf is shown by S3 in Fig.2. Its spectral absorbance intensity decreases gradually with the wavelength λ . It has no spectral feature of normal green leaf with high absorbance in red and blue ranges and low absorbance in green and short-wave infrared ranges.

2.3 Differential absorbance spectrum of leaf sample

Healthy leaf reflects infrared light and green light but absorbs red light. SPAD-502 meter utilizes two light-emitting diodes (LEDs) with central wavelength of 640nm and 950nm respectively to measure the relevant absorbance of light. In Fig.2, in the NIR range from 760nm to 900nm, sample absorbance spectra change only in the vertical dimension. To get a uniform baseline for the ease of comparison, a new concept named Differential Absorbance Spectrum (or DAS for short) is adopted to measure the difference between leaf samples.

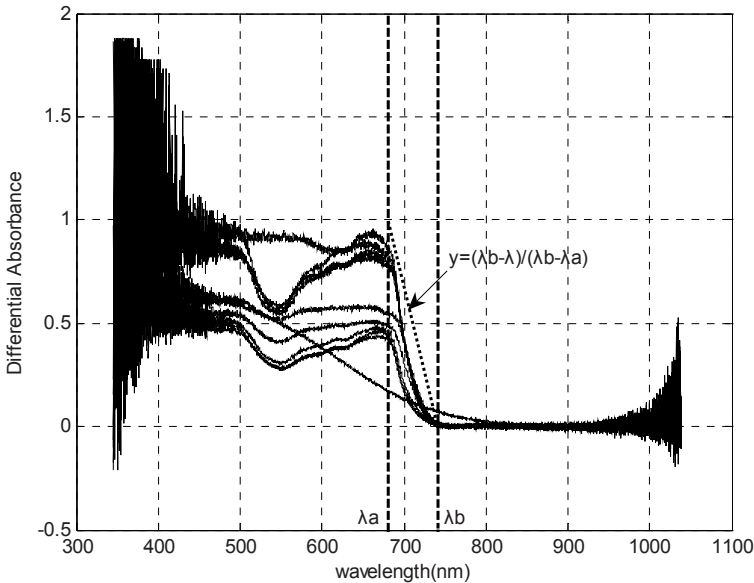


Fig.3: Typical differential absorbance spectra of leaf samples

Let $DAS(\lambda)$ differential absorbance rate at wavelength λ , then

$$DAS(\lambda) = ABS(\lambda) - AVR, \lambda \in (346.01-1038.08\text{nm}) \quad (3)$$

where, AVR is the average absorbance from 800nm to 900nm. The typical differential absorbance spectra of leaf samples are shown in Fig.3. Each DAS in the range from 760nm to 900nm approximates to 0; the DAS in red side range from 650nm to 750nm decreases monotonously to 0.

2.4 Genetic algorithm for leaf chlorophyll level modeling

Based on the observation of the absorbance spectra of leaf samples, we find it feasible to build leaf chlorophyll prediction model in the spectral range of 650-750nm. Let $\lambda 1$ the lower limit, $\lambda 2$ upper limit. Since SPAD-502 meter uses two LEDs as light sources whose spectra have a fixed width with very weak intensity in the upper and lower borders. Thus, we design an adjustable factor of light intensity to modulate the differential absorbance spectra,

$$\alpha = \frac{\lambda 2 - \lambda}{\lambda 2 - \lambda 1} \quad (4)$$

If $\lambda = \lambda 2$, then $\alpha = 0$, that would force the DAS at wavelength $\lambda = \lambda 2$ to 0; If $\lambda = \lambda 1$, then $\alpha = 1$, that would keep the original light intensity unchanged.

Besides, we must consider the influence of leaf thickness in the modeling above. As SPAD-502 meter uses LED's light transmission, leave thickness has been concluded in its measuring result. However, fiber-optic reflection spectrometer can only get the information of leaf surface. According to Beer-Lambert law, the transmission intensity is linearly proportional to the light path so that its absorbance rate is logarithmically proportional to leaf thickness. Thus, the influence factor of leaf thickness can be designed as follows,

$$\beta = K[\log_{10}(\text{thickness}) + T] \quad (5)$$

where K and T are the parameters undetermined.

Totally, the prediction equation of leaf chlorophyll level can be entirely written as,

$$PRED = K[\log_{10}(\text{thickness}) + T] \sum_{\lambda=\lambda 1}^{\lambda 2} \left[(ABS(\lambda) - AVR) \frac{\lambda 2 - \lambda}{\lambda 2 - \lambda 1} \right] \quad (6)$$

where, $\lambda 1$, $\lambda 2$, K and T are the parameters to be determined. Due to the nonlinearity of equation (6), it is difficult to determine the four parameters analytically. In the test, a genetic algorithm (GA) is designed for the parameter optimization.

The procedure of GA is designed as follows,

Step1: All 70 samples in calibration set C are used to parameter optimization.

Set initial population size 50, each individual with four parameters λ_1, λ_2, K and T . Each parameter is 16 bits wide. The individual fitness function is like,

$$\text{Fitness} = \sum_{i \in C} |\text{PRED}(i) - \text{REAL}(i)| \quad (7)$$

where $\text{PRED}(i)$, $\text{REAL}(i)$ is the prediction value and real value of the i^{th} leaf sample's chlorophyll level. GA termination condition is to run 1000 times.

Step2: Startup GA and generate 50 individuals randomly to form the initial population.

Step3: Calculate the fitness of each individual according to the equation (7). The four parameters with minimal individual fitness in each iterative calculation are kept as the elitist individual. Tournament selection strategy is adopted to renew the population.

Step4: Crossover operation is conducted on the renewed population. The individual number for crossover operation is 20 with the crossover rate of 0.2. Then mutation operation is performed on each individual with total bits of 10 and mutation rate of 0.01.

Step5: The iterative number decreases by 1. If it reaches to 0, the GA ends, or else, the GA returns to step 3 for next iteration.

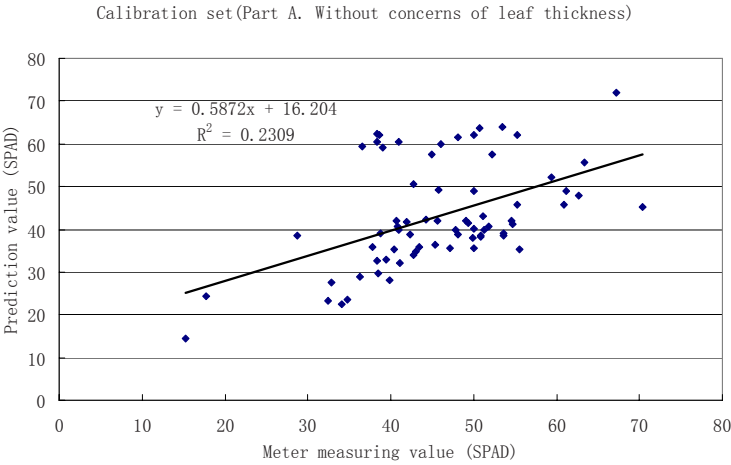
Terminally, the optimal result through GA calculation is,

$$\text{PRED} = 0.417[\log_{10}(\text{thickness}) + 3.689] \sum_{\lambda=\lambda_1}^{\lambda_2} \left[(\text{ABS}(\lambda) - \text{AVR}) \frac{\lambda_2 - \lambda}{\lambda_2 - \lambda_1} \right] \quad (8)$$

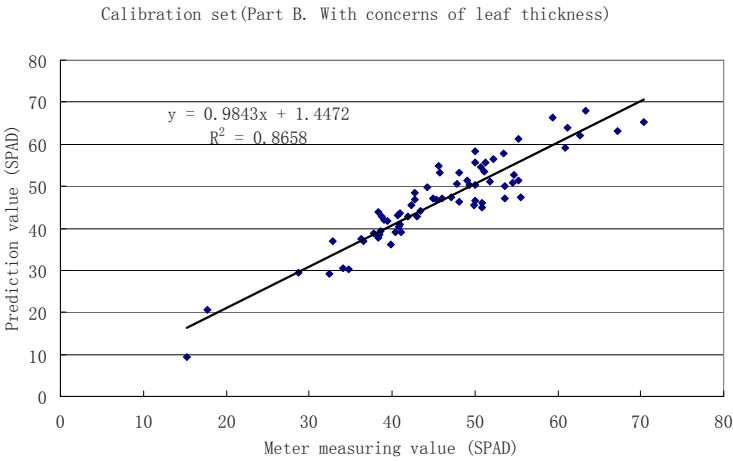
($\lambda_2 = 683.24\text{nm}$, $\lambda_1 = 733.91\text{nm}$)

3. RESULTS

Leaf chlorophyll statistics regression of calibration set is shown in Fig.4. Part(a) is the result of regression between spectral prediction and meter measurement without leaf thickness adjustment. The regression coefficient $R^2=0.2309$, which is very low. Part(b) is the result when the leaf thickness factor is integrated in the calculation. The regression has been improved a lot with $R^2=0.8658$. It proves that leaf thickness is an important factor in the modeling of reflective spectroscopy of leaf chlorophyll level. Similarly, the statistics regression of verification set also shows the point (see Fig.5). $R^2=0.5675$ (a) without concerns of leaf thickness factor can be improved to $R^2=0.9161$ (b) when adding leaf thickness in the modeling.



(a)



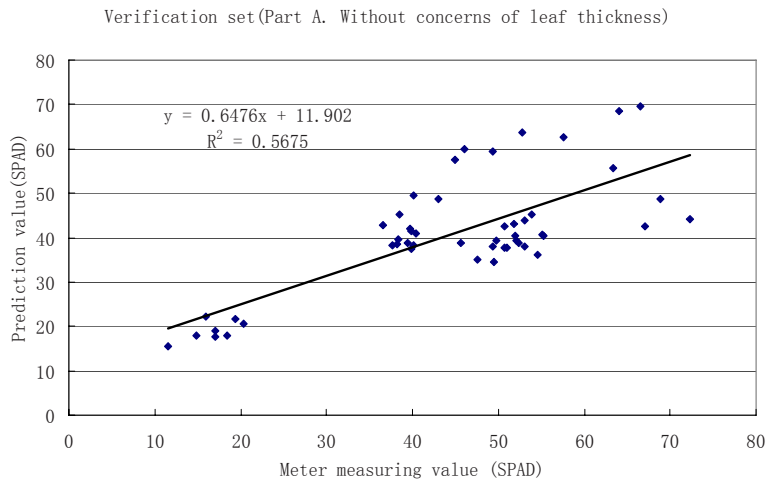
(b)

Fig.4: Leaf chlorophyll statistics regression of calibration set

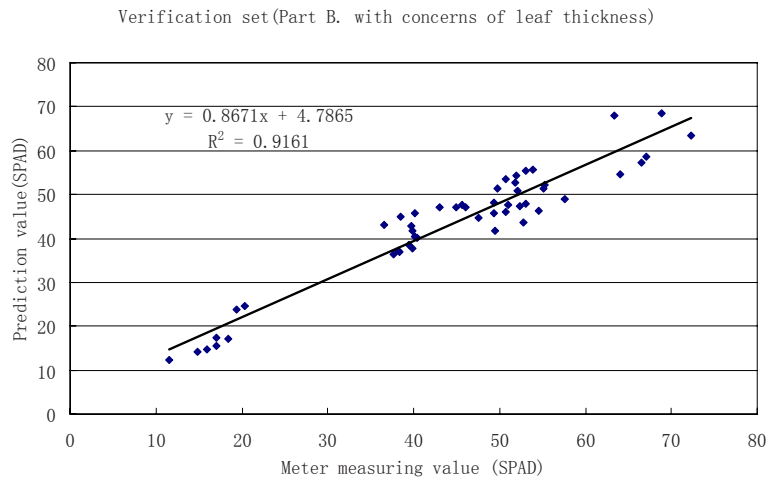
4. CONCLUSION

In the study, reflection spectroscopy technique was examined in the modeling of leaf chlorophyll level. The result shows that various factors should be put into consideration for the accuracy of spectral modeling. One essential facet is the leaf thickness which has an important effect on the model accuracy. Through observation of absorbance spectral curves, it was found that the spectral range from 650nm to 750nm is significant for leaf

chlorophyll model. A genetic algorithm was used to determine the optimal range 683.24-733.91nm. Besides, an adjustable factor of light intensity was designed to simulate the LED's narrow spectral limitation of SPAD chlorophyll meter to improve the model accuracy. The test proved it reasonable. The prediction model based on reflection spectroscopy has been verified by USB4000 modular spectrometer and could be used as a quantitative model of leaf chlorophyll level.



(a)



(b)

Fig.5: Leaf chlorophyll statistics regression of verification set

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PLANTING-DENSITY OPTIMIZATION STUDY FOR TOMATO FRUIT SET AND YIELD BASED ON FUNCTIONAL-STRUCTURAL MODEL GREENLAB

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Abstract: Quantification of tomato's fruit-sets depends on the level of competition for assimilate in different environment, and this paper presented some results of fruit yield and quality (fruit size) in response to environment (mainly respect to and planting-density and light) . Some experiments had been carried out to find the relationship between growth rules of tomato and plant densities. A structural-functional model GREENLAB has been developed to simulate it. The results show that increasing plant density results in an increment of biomass production on a ground area but in a reduction of single plant fresh weight. To find rules between organ sink and source relationship, calibrations were made based on the target data of different plant density in the model. Environmental conditions were introduced into the model checking the influence on Q/D over plant growth period and fruit set ratio. It is found that changing the Q/D ratio in some critical periods can be used to optimize fruit set and yield of greenhouse tomato.

Keywords: tomato, structural-functional model, fruit set, sink and source, yield and quality.

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1. INTRODUCTION

In spite of rapid developments in recent years, greenhouse environment control and cultivated management practices in China are still lower than in developed countries. This results particularly in lower yield and inferior quality of Chinese products as compared to the standards of international market (Heuvelink,2005). The development of tools, which allow optimizing greenhouse climate and management practices in order to maximise yield and quality are thus highly desirable and encouraged.

Crop growth models coupled with greenhouse climate represent the most promising approach to fulfil these objectives. Concerning tomato, several authors have proposed mechanistic models predicting growth and development through a set of equation describing the main physiological functions involved in carbon balance (TOMGRO: Jones et al.,1991; TOMSIM: Heuvelink,1999). These models have demonstrated their ability to simulate productivity and yield in various conditions but present the main drawback of being rather complicated to use in optimization procedure. The mathematical model GREENLAB (Guo et al.,2006) is a structural-functional model, which describes the plant architecture at the organ level, simulates resource dependent plasticity of this architecture and allows to computing plant geometry. Contrary to the previous attempts this model is particularly designed to be used in optimization. It has been shown that relative strength of fruits influences both yield and quality (Guichard et al.,2001), yield and quality was considerably affected by planting density and light conditions. In the current version, fruits are described as a whole at the truss scale. In this study the GREENLAB-Tomato model will be parameterized for different homogenous planting densities.

2. MATERIALS AND METHODS

2.1 Experimental design

The studies are based on experiments and measurements on tomato (*Solanum Lycopersicum* L., 'ZhongZa 9'). Plants were grown in regularly spaced 7-L pots in solar green house at the Chinese Academy of Agricultural Science in Beijing (39.55N, 116.25E) .Two experiments are designed. The first experiment (exp1) intends to verify potential growth assumption, the secondary experiment (exp2) studies the relationship between tomato growing conditions in green house and fruit set, the environment condition respects to light mainly.Exp1 was repeated twice with same density

(3plants/m²) in autumn of 2006 and spring of 2007,we pruned fruits and left the first fruit set from the first truss in 2006,the first fruit set from the second truss in 2007.Exp2 was repeated twice in spring of 2007 and autumn of 2007 with four densities (Table 1) each, no irrigation and fertilization stress, plots of 30 plants were surrounded by two rows of guard plants, when a plant was destructively harvested, it was replaced by a comparable plant in order not to disturb the light distribution among the plants, detailed topological observation were made throughout the development of the plants. Additionally, meteorological data (PAR, temperature, humidity stored by Galileo-LPS 2000 Data-logger) to parameterize the model and number of flower buds initiation, flowers, fruit sets ($\Phi > 10\text{mm}$) to characterize fruit development were recorded during growth and development of plant.

Table 1. plant density treatment design

treatment	plants/m ²
High density (hd)	11
High-intermediate density(md1)	6
Intermediate density(md2)	3
Low density(ld)	1

2.2 Model description

There are two biological laws used in GREENLAB model, Firstly, the organs production of plants are linked proportionally to the sum of temperatures, the thermal time relates to a new metamer named as “growth cycle”. Secondly, the biomass production is linearly correlated with the water transpiration (Potential Evapotranspiration: PET)(FAO guidelines; Allen et al.,1998). Main equations of GREENLAB:

The ith cycle total matter production is

$$Q(i) = \frac{E(i)S_p}{r_1r_2} \left(1 - \exp \left(-r_2 \frac{\sum_{j=1}^{n(i)} S_j}{S_p} \right) \right) \tag{1}$$

Where: Q(i) is the matter production during the cycle i, E(i) is growth potential during the ith growth cycle, Sp is the projection surface of one plant, r1 is blade resistance, r2 is a competition factor, leaf overlapping

effect on PET, $\sum_{j=1}^{n(i)} S_j$ is total leaves surface at ith growth cycle.

$$E(i) = 0.91 * PET(i) \tag{2}$$

Where: PET(i) is Potential Evapotranspiration at ith growth cycle, used FAO-radiation Equation, 0.91 is an optimized parameter.

J aged organ at plant ith cycle biomass increment is

$$\Delta q_o(i, j) = \frac{P_o \cdot f_o(j)}{D(i)} \cdot Q(i-1) \quad (3)$$

Where: $\Delta q_o(i, j)$ is j aged organ o (o =internode, blade, petiole, fruit, root, layer) at i th growth cycle increased biomass, P_o is organ sink, $f_o(j)$ is organ

sink variation function(beta law), $\sum_{j=1}^i f_o(j) = 1$, i is organ expansion duration.

Demand of plant at i th growth cycle is

$$D(i) = \sum_{o=b,p,e,f} P_o \cdot \sum_{j=1}^i f_o(j) \quad (4)$$

Where: $D(i)$ is plant demand at i th growth cycle

In model parameters are divided two groups: directly measurable group and hidden group, first group like organs geometry, function time of leaves, organ's expansion time etc, second group calibrated from directly measurable one like: P_o , f_o , r_1 , r_2 . Some target files got by destructed experiment in several growth stages for all the organs are used to multi-fitting to get hidden parameter, The sink strength of the blade(P_{blade}) is set to 1 as a reference.

3. RESULTS AND DISCUSSION

3.1 At same density, individual fruits display a determinate growth, all fruit have same potential sink strength

Potential growth is defined by the growth which would be realized if no factor is limiting, that is, when assimilate supply is higher than or equal to assimilate demand (Bertin, 1995). Fig.1 shows that at same density individual fruit growth curves is similar between exp1 and exp2, individual fruits are likely to display a determinate growth, different source did not result in different final maximum fruit growth biomass, and the final fruit size may reach a extreme, while fruit abortion favor assimilation distribution towards the vegetative plant parts (Marcelis, 2004), not fruit. Fig.2 shows that delay between set remains constant. The delay between position of the truss on the stem and position of the fruit within the truss result in gradient of attract biomass ability. It is to say at one density every fruit behave the same but at different moments. This means same sink, same expansion time

and expansion rule but different apparition time, so a single set of sink parameters is able to represent all fruit for one density.

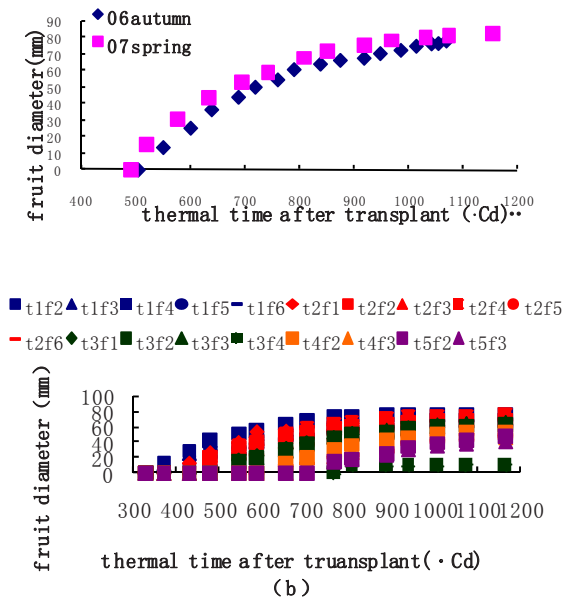


Fig 1: fruit diameter development with one fruit per plant in exp1(a) and with all fruits reserved in exp2(b) in same density(3p/m²)
tx is truss number on stem above cotyledon , fy is fruit number from base on one truss, absence is no fruit on this position.

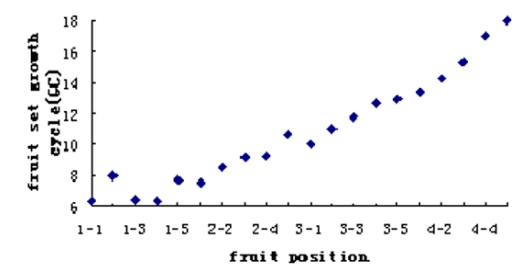


Fig 2: The fruits set growth cycle in each trusses

3.2 Multi-fitting results on the hidden parameters for different density

Where: Ppetiole ,Pinternode , Pfruit are organ sink of the petiole, the internode and the fruit , bblade , bpetiole , binternode , bfruit are parameter b

of extension beta-law function for each organ type, another function parameter a is constrained to 2. Fit results show that the sink of organs changes with density increase, For fruit, the higher the density is, the lower the sink will be, while for internode, the result is reverse. This is consistent with the observation: in high density, the internode is longer than in low density, but the fruit is smaller.

Table2. hidden parameters for different density

parameter	LD	MD1	HD
$Q(0)$	0.08	0.08	0.08
$P_{petiole}$	0.6	0.7	0.8
$P_{internode}$	0.5	0.6	0.8
P_{fruit}	14	13	11
b_{blade}	2.3	2.2	2.4
$b_{petiole}$	2.2	2.7	2.6
$b_{internode}$	1.8	2	1.9
b_{fruit}	4	8	9

3.3 Different yield in different plant density result from environmental conditions action on Q/D

Increasing plant density results in an increase of biomass production on a ground area but in a reduction of single plant fresh weights (Fig.3) . Environmental conditions act on Q/D on plant growth (Fig.4) , the number of developing fruits is the overall result of the flowering rate, the number of flowers initiated per truss and the incidence of abortion of flower buds, flowers and fruits (Koning, 1994).To find rule between Q/D during critical periods and initiation bud number, flowering rate, fruit set rate, calibration is done on data of different plant densities in the model (Table 3,4,5).

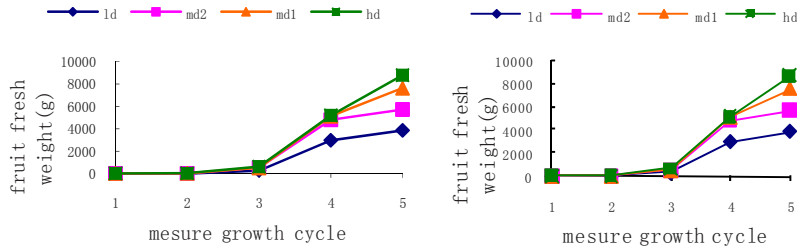


Fig. 3: tomato fruit fresh weight on one plant and one centiare in different density

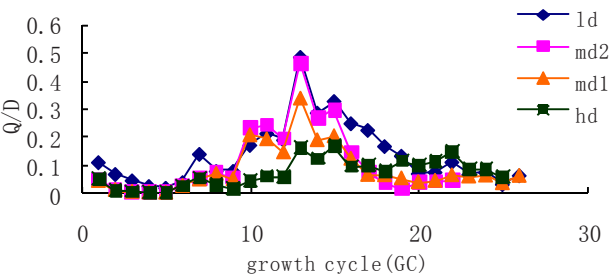


Fig.4: Q/D ratio over the plant growing period

Table 3: Q/D during GCs of bud initiation and the number of initiated flower buds

treatment	Q/D	Init Flower buds per truss
ld	0.09	6.1
md2	0.07	6
md1	0.04	5.8
hd	0.02	5.7

Table 4: average Q/D of GCs between 50% bud emergence and 50% flowering with flowering rate

treatment	Q/D	flowers	Flower rate
ld	0.29	5.8	95%
md2	0.29	5.8	96%
md1	0.21	5.5	95%
hd	0.1	5.1	89%

Table5: average Q/D of GCs between 50% flowering and 50% fruit set with fruit set rate

treatment	Q/D	Fruits per truss	fruit set
ld	0.29	4.4	75%
md2	0.17	4.2	72%
md1	0.15	3.7	67%
hd	0.11	2.8	55%

To contrast the Q/D of GCs of bud initiation with the number of initial flower buds, we average Q/Ds values during this period which last several GCs from the first flower bud emergence on one truss to the number of flower bud being stable for four densities each. Result showed that increasing density tends to reduce initial bud number (though difference is not distinct). This is consistent with the trend of average Q/D of GCs during bud initiation (Table 3). We define average Q/D of GCs between 50% bud emergence and 50% flowering as flowering rate, average Q/D of GCs between 50% flowering and 50% fruit set as fruit set rate. Table 4 and table 5 show reductions in average Q/D of corresponding GCs could be related to the decrease of flowering rate and fruit set rate.

4. CONCLUSION

Individual fruits display a determinate growth, so a single set of sink parameters is able to represent all fruits in same density, there are gradients for one organ sink parameter in different densities. GREENLAB-Tomato model can represent it.

Density reflects different environment factors, increasing densities strongly reduce individual plant biomass, the initial bud number, flowering rate, fruit set rate. In high density, the fruit is smaller than in low density, but the leaf and internode are bigger. This can be explained by competition for assimilation among organs: the change of Q/D ratio in critical periods may change the ratio between vegetative growth and reproductive growth, which can be done through optimizing greenhouse climate control. Greenlab can fit the resource-dependent phenotypic plasticity induced by plant spacing and light availability

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SUSTAINABLE AGRICULTURAL PARADIGM OF MOUNTAIN-OASIS-ECOTONE-DESERT SYSTEM IN INLAND MANASI RIVER BASIN, XINJIANG PROVINCE, NORTHWEST CHINA

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Abstract: Manasi River basin is located in the north foot of Tianshan Mountain, south edge of Zhunger Basin, central-north Xinjiang province, with typical arid features of northern China. As the pressure on water resources in Manasi river basin is mounting because of rapid economic development, its conservation becomes ever more important. Climate change is another major threat to the future of water resources of Manasi river basin. How the water resource changes in Manasi river basin caused by glacial ablation, will affect the typical mountain-basin terrestrial ecosystems and agricultural production in Manasi river basin? What can we cope with the ecological issues caused by glacial ablation? In this paper we show how the water-saving stratagem such as constructing reservoir in the mountainous region, building water pipes and generalizing water-saving technology in upper, middle and lower reaches can be used in combination with the potential of water-saving resources, and build up sustainable agricultural paradigm of mountain-oasis-ecotone-desert system to coping with the glacier retreat and ablation. The potential of water-saving in study area were calculated which presumed that if mountainous reservoirs and water pipes were built and water-saving technology were adopted, 3.46×108m3 irrigating water could be saved one year in these oases. The optimized eco-productive paradigm for mountain-basin system in Manasi river basin is proposed in desertification controlling, constructing artificial

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grassland in the oasis is the measure to protect vegetation in the downstream desert in Manasi river basin, and stopping grazing or forbidding grazing in the downstream of serious degradation in Manasi river basin.

Keywords: the optimized eco-productive paradigm, groundwater, land use change, oasis, runoff, Manasi River watershed

1. INTRODUCTION

The complex of mountain-basin terrestrial ecosystems, or mountain-basin system (MBS) for short, in the north of the Tianshan Mountains, Manasi river basin, consists of mountain vegetation vertical belt system and concentric circular vegetation (geologic and geomorphic) system of desert basin. The MBS contains three “circles”: montane, piedmont fan and alluvial plain, including nine belts. Viz. alpine belt, montane forest-grassland belt, low-mountain desert belt, gravel gobi desert belt, agricultural oasis, marginal belt of diluvial fan, alluvial desert plain, sandy desert belt, and lake. The above-mentioned zonation is the most essential existence and functional pattern of those precious natural resources(Zhang, 2001).

The sustainable agricultural paradigm of mountain-oasis oasis/desert ecotone-desert system (MOED), which is gradually demonstrated, and based on the profound scientific foundation, can be used as ecological conservation, reconstruction and the adjustment of agricultural structure. It is the presentation of an irresistible rule of the nature and, also, the gsystem of ecological conservation and land use. The MBS is its basic frame(Zhang, 2000). Thus, the establishment of a sustainable agricultural system and an optimized land use/cover structure and patterns in Manasi river basin, which aimed at ecological conservation, may be possible.

As the pressure on water resources in Manasi river basin is mounting because of rapid economic development, its conservation becomes ever more important. Population growth, increased incomes and urbanization have joined forces and agriculture cannot keep up with the increasing demands of this emerging, new community. To sustain the increased demand for more and diverse agricultural products in Manasi river basin, it is ineuidance vitable that the acreage of irrigated area will increase over the years.

Climate change is another major threat to the future of water resources of Manasi river basin. Widespread accelerated glacier retreat and melt water in stream flow timing, from spring to winter, are caused by climate change. There are serious concerns about the alarming rate of retreat of glaciers. In the short run the glacier melt may increase water availability, but eventually

the base flow from glaciers will cease(Shi, et al., 1990; Shi, et al., 1999; IPCC, 2001). In general, Temperature rise and meltwater increase during the first half of this century are favorable to the development of irrigated agricultural and economic growth of Manasi river basin in the early and middle part of this century, which is located in in the north slopes of the Tianshan Mountains, southern margin of the Junggar Basin(Shi, 2001; Lai, 1986). However, after peak value of meltwater in the later part of this century, meltwater curtailment because of glacier Shrinkage, will intensify the lack of water resource.

How the water resource changes in Manasi river basin caused by glacial ablation, will affect the typical mountain-basin terrestrial ecosystems and agricultural production in Manasi river basin? What can we cope with the ecological issues caused by glacial ablation? And what can we improve the management of water resource utilization and agricultural structure to adapt to increase of glacial melt water?

In this paper we show how the water-saving stratagem such as constructing reservoir in the mountainous region, building water pipes and generalizing water-saving technology in upper, middle and lower reaches can be used in combination with the potential of water-saving resources, and build up sustainable agricultural paradigm of mountain-oasis-ecotone- desert system to coping with the glacier retreat and ablation.

2. STUDY AREA

2.1 Geographic location

Manasi river basin which belongs to Shihezi city, Shawan and Manasi countries in administrative division, is located in north of Tianshan Mountain, South Margin of Junggar Basin. It is between 43°27'-45°21'N、85°01'-86°32'E, total area $2.29 \times 104 \text{ km}^2$, mountain and plain in half.

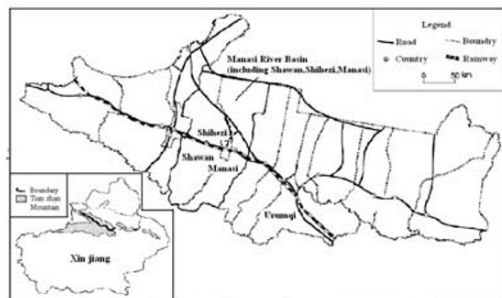


Fig. 1 Administratively Area of Oasis Economy Belt of Northern Slope of Tianshan Mountain in Xinjiang

2.2 Terrain and landforms

The terrain of Manasi river basin is higher in the southern rather than the northern part. The highest elevation is 5,242.5m in the southern mountainous area of Manasi river basin. The permanent ice and snow covered areas are distributed above a 3,900m attitude of high and extra-high mountain areas. The distribution areas of alpine cushion vegetation and lichen are about 3,200-3,900m in altitude. Alpine meadow with an altitude of 2,300-3,200m above sea level, and spruce forest with an altitude of 1,650-2,850m above sea level. Mountain grassland and desert grassland distribute in the elevation of 1,100-1,650m and 800-1,100m above sea level, respectively. The plain area below 800m altitudes are the eco-tone between oasis and desert. According to vertical and horizontal position, the spatial position is in sequence of temperate desert grassland (the alluvial fan, elevation 410-800m), temperate meadow-swamp-saline vegetation (the marginal belt, elevation 370-410m), temperate desert (the alluvial plain, elevation 350-370m), temperate sand vegetation (the plain and desert, elevation 260-350m), temperate salt-marsh vegetation (the lacustrine deposit plain), from piedmont to the in-depth research of the desert. Relying on Manasi river basin, oasis on the forms of belt and patch is distributed in the piedmont alluvial-pluvial fan, alluvial fan marginal belt, and alluvial plain.

2.3 Climate

The climate of Manasi river basin is of continental climatic type. The annual and daily differences in temperature are big. The annual mean temperature is 6.6°C, the annual mean precipitation 110-200 mm, accumulated temperature of more than 10°C 2,400-3,500°C, annual average wind speed 1.7 m/s. The water resources in Manasi river basin is abundant, which has five inland rivers, in the sequence of Taxi river, Manasi river, Ningjia river, Jingou river, Bayingou river, from east to west. The five inland rivers which originated from the northern foot of Tianshan mountain,

and flow into Junggar Basin. The total amount of water resource in Manasi river basin is $25.73 \times 10^8 \text{ m}^3$, and about $22.91 \times 10^8 \text{ m}^3$ of stream flow available for development and utilization, in addition, there are also $11.97 \times 10^8 \text{ m}^3$ of groundwater resources non-repeated with Surface Water in the piedmont plains.

3. THE LAND USE CHANGES AND WATER RESOURCES IN MANASI RIVER BASIN

Manasi river basin is located in north of Tianshan Mountain, South Margin of Junggar Basin. The natural environmental of Manasi river basin is a complex of mountain—basin terrestrial ecosystems, or mountain-basin system (MBS) for short. The stability of oasis in Manasi river basin is determined by the ecosystem structures, functions and ecological process, and directly related to sustainable development of regional society and economy. The condition of land use changes and water resources are as follows.

3.1 The processes of land use changes in Mnasi river basin from 1949 to 2001

Based on “3S” technology and images, Chen Weiming et al. studied the spatial and temporal changes of oasis in almost over 50 years from 1949 to 2001, by using the datasets of 1:100, 000 topographic map(1962), Landsat MSS(1976/06/15), TM(1989/08/09), ETM(1999/07/04, 2001/08/15), and get the conclusions(Tab.1):

Tab.1 Area Change of Oasis Landscape over Last 50 Years in Manas River Basin (Chen Weiming et al.2005)

Land use Types	1949	1962	1976	1989	1999	2001
Farmland	156.385	2,750.458	3,639.491	4,234.008	4,427.377	4,568.254
Artificial Garden	—	0.434	15.632	29.660	29.598	30.905
Artificial Reservior	—	7.319	48.335	81.108	78.903	107.642
Town	—	18.706	22.481	59.359	70.536	75.713
Village	—	169.133	186.563	206.647	245.115	256.845
Building	—	0.0	0.0	0.427	1.004	2.717
Area of oasis	156.385	2,946.050	3,912.502	4,611.209	4,852.533	5,042.076

As Table 1 showed, the expansion between oasis and farmland are synchronized and agriculture is the leading industry in Manasi river basin. The process of oasis extension is divided into two stages.

The rapid expansion (1949-1976): with rapid expansion of original oasis and exploitation of new opening oasis, they are joined by each other; the steady development of oasis (1976-2001): the outline of oasis from north to south is not extended, and the main changes are in inner artificial oasis. Saline land mostly distributed in low ground of the desert margins, which has been the concentration area of salinity (Chen et al., 2005).

3.2 The processes of land use changes in Mnasi river basin from 1949 to 2001

I The runoff forming district (montane fan) in Manasi river basin

Mountainous area is the flow concentration area in Manasi river basin, the mean annual precipitation is 700-1000mm, and the area of glaciers is 1228km². The mean annual precipitation of the mountainous area which is below the glaciers is 408mm and area is 6006km². Mountainous area has the function of water resource conservation and ecological maintenance. The mean forest cover rate is only 5.5% and forest density has already decreased from 0.9% to 0.3%. The area of dominant specie *P.schrenkiana* is only 237.5km² and the cover rate is 2.8%, and the rest forest is the secondary plantation with low water resource and ecological sustainable function. Meanwhile, vegetation degradation caused by forest and grass destroy, overloading and overgrazing, diseases and insect pests, soil erosion are ubiquity in mountainous area..

II Runoff-dissipating district (piedmont and alluvial plain) in Manasi river basin

Piedmont fan is the distribution in oasis and runoff-dissipating district, and it is the distributed areas of towns, industry, and agriculture, track network, where it is the core area of using high efficient artificial technology to convert water resources and creating social wealth. The area of oasis is 6,534 km². To the effective and reasonable utilization of runoff from mountainous area, people traditionally depended on developing water conservancy, hydropower and irrigation facilities. At present, the total length of built-up channel is 22,296 km, the amount of reservoir more than thirty. The irrigating water from mountainous area is only thirteen billion m³, the utilization Ratio of water resources from mountainous area is 57%, repeated utilization ratio 9.1 billion m³, and annual regulating water storage capacity accounts for 17.4% of annual runoff..

III Sandy desert district in the downstream of Manasi river basin

The area of sandy desert district in the downstream of Manasi river basin is about 10,000 km², and the annual precipitation is below 100mm. The amount of evaporation is about ten times higher than precipitation. The growth of desert vegetation depends on leakage water from the oasis, but these vegetations are the essential ecological barrier against the ecological disaster, such as dry-hot wind, sand flow, desertification, salinization and alkalization. Because of the extension of oasis and rapid increase of interception diversion, the amount of water resources in the down stream falling sharply, and even setting off. As the surface water over utilization and ground water excessive exploitation, underground water level decreases sharply, this causes Manasi lake shrinkage and lake level reducing even drying up. The pasture and meadow with high quality and yield in the plain successive disappeared, directly to the succession of desert or sparse vegetation landscape stages.

Desert is often taken as no any production and ecological function areas. Sparse desert vegetation is cut and destroyed a lot to result in sustainable deterioration of desert ecosystem. The ecological supplying water on desert grassland is little and not to sustain water demands of grassland and forest trees in the downstream of Manasi river basin. The deterioration of desert grassland in alluvial desert plain is resulted in the water resource deterioration which is the grassland depended on.

4. SUMMARY AND CONCLUSIONS

The main ecological and environmental problems that Manasi river basin are faced on, are divided into three kinds, which are all related to water resource.

The first kind is the trend of decreasing and degrading of forest and grassland in the runoff forming district of Manasi river basin, and forest coverage declining. The area of dominant species *P.schrenkiana* decreased a lot. It is urgent to prevent the deterioration of forest and grassland at prime tense and restore the function of water conservation.

The second kind is a large quantity of melt water caused by glacial ablation, and the contribution of the stream flow from glacial ablation is much greater. Farmland in the lower area is submerged, while the distribution range and area of saline land is increasing. The unreasonable irrigation in Manasi river basin resulted in secondary salinization and a lot of low middle yield field, even the abandonment of land use began to increase notably almost in the same time. Sandy desert belt along the lower marginal belt of oasis is the discharging area of saline-alkaline. In recent years, most

drainage system of saline-alkaline opened into desert, which has become the concentration area of saline-alkaline and had important influence on the growth of psammophilous vegetation.

The third kind is the over grazing in the downstream of Manasi river basin, where it is the sandy desert belt. Over grazing obviously accelerates desertification in the downstream. Desert vegetation has a large amount of death, and the desert is significantly enlarging and moving towards south annually.

The forth kind are outstanding problems of insufficient regulation capability of reservoirs. The annual water storage capacity of Manasi river basin occupied 17.4% of the total runoff. A large amount of incoming water during flood season (late summer and autumn), almost wastes without utilization, but drought and water shortage during dry season (spring and early summer) are restricting seriously the food production and social economic development. Serious seepage canal system and background irrigation, and water diversion rate is lower than 50%. High efficiency water saving methods of sprinkler irrigation, drip irrigation, and infiltration irrigation are not applied. The traditional extensive water diversion leads to the fact that water resources are wasted, the elevation of groundwater level and salinization of soil on large range.

5. THE OPTIMIZED ECO-PRODUCTIVE PARADIGM FOR MOUNTAIN-BASIN SYSTEM IN MANASI RIVER BASIN

What can we improve the management of water resource utilization and agricultural structure to adapt to increase of glacial melt water? How much water volume can water saving measures be saved? How much potential does water saving measures have? They are important strategies of the above ecological problems and water resource management of the whole river basin. They are also the important basis on making river basin management mode and water management target.

I Banning grazing in mountainous belt of Manasi river basin and protecting water conservation forest (dominant species *P.schrenkiana*)

The degeneration of ecological environment, such as vegetation degradation, soil erosion, diseases and insect pests, forest and grassland destroy, overloading and overgrazing, has been more serious.

The domain species, spruce forest distributed in altitude ranging from 1650m-2850m, in mountainous area of Manasi river basin. Human disturbance to herbaceous layer is becoming more serious to cause great threats to natural regeneration of mountain forest. Meanwhile, disappearance

of herbaceous plant caused the bare surface, which changed the land surface reflectance and caused soil water content decreasing. Mountainous forest could prevent dry hot air flow arising from desert. In recent years, the implementation of natural forest conservation protects woody plant but ignore herb plants, which are taken as one of the most important component of forest ecosystem. It is necessary for the whole recovery of forest ecosystem including herb plants and construction of valley forest.

According to the analysis of vegetation characteristics in different altitudes of Manasi river basin, the different countermeasures of recovery are performed: natural restoration of alpine meadow from the elevation of 2,300m to 3,200m; natural restoration combined with artificial restoration of spruce forest from the elevation of 1,650m to 2,850m, and mountain grassland from the elevation of 1,100m to 1,650m.

II Improving high efficiency and intensive utilization of water resources

1. Building up reservoirs in mountainous area and storage of melt water and runoff that are caused by global warming and glacial ablation

Analysis of reservoir's water-saving potential in mountainous: runoff and melt water almost appears in summer, and in the next decades, increasing of melt water and runoff cause water resources relative surplus in summer and deficiency in spring. Building up reservoirs in mountainous area to accumulate melt water and runoff and reducing evaporation loss of reservoirs in the desert plain, in order to supply more water resources, which will increase 15-20% water supply.

2. Building up water Pipeline to prevent evaporation and leakage

Analysis of water-saving potential of water conveyance system: Statistical value of canal-system water use efficiency is 0.57 (Li et al, 2007), if it would have been 0.67 by canal seepage control, development of water conveyance pipe and decreasing evapotranspiration. There will be saving water 1.3 billion m³ in water conveyance system of Manasi river basin.

3. Extension of field water saving technology

Analysis of farmland water saving technology: the irrigating water from mountainous area is only thirteen billion m³, the utilization Ratio of water resources from mountainous area is 57%. If the utilization ratio of water resources would be 67% which increases 10%, the whole river basin will be saving 1.3 billion m³. Water repeated utilization ratio in the field is only 9.1 billion m³. If Water repeated utilization ratio would have been 10 billion m³ in the oasis, with developing salt water irrigation technology and cultivating halophytic vegetation, water resources would be saved 0.9 billion m³. Annual water storage capacity accounts for 17.4% of annual runoff. If it is increased to 27.4%, water resources would be saved 1.26 billion m³.

Combined with above three methods, water resources would be saved 3.46 billion m³.

III Desertification Controlling

1. Desertification controlling in Manasi river basin should be based on water saving agriculture

Desertification controlling in downstream of Manasi river basin, implementation of normal supply water use in the oasis and desert grassland, should be based on water saving agriculture. Surface diversion is seriously excessive, but utilization efficiency of water is very low. The water efficiency in field canal system of irrigation is 0.57. Because of the serious loss of water and low production efficiencies, energy consumption per unit GDP and agricultural water consumption is 6 times of national average level. The benefits of water consumption per m³ are a quarter of the country average level. Fully exploit potentialities of water would promote conservation of desert ecosystem.

2. Constructing artificial grassland in the oasis is the measure to protect vegetation in the downstream desert in Manasi river basin

A large amount of pasture is ingested in the downstream of Manasi river basin. Planting artificial grassland with high yield, improving forage output in the unit area, increasing supply of forage grass and feed, which decrease livestock number, grazing time and grazing pressure of desert grassland, finally achieved the ecological exchanges from natural grassland grazing to artificial grassland barn feeding.

3. Stopping grazing or forbidding grazing in the downstream of serious degradation in Manasi river basin

We could adopt protect first and prevent grassland from further degradation as the dominant factor and proper light grazing in desert grassland. Control grazing period and grazing capacity, and relief the pressure of grassland grazing.

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GIS-BASED CROP SUPPORT SYSTEM FOR COMMON OAT AND NAKED OAT IN CHINA

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Abstract: The identification of the suitable areas for common oat (*Avena sativa* L.) and naked oat (*Avena nuda* L.) in China using Multi-Criteria Evaluation (MCE) approach based on GIS is presented in the current article. Climate, topography, soil, land use and oat variety databases were created. Relevant criteria, suitability levels and their weights for each factor were defined. Then the criteria maps were obtained and turned into the MCE process, and suitability maps for common oat and naked oat were created. The land use and the suitability maps were crossed to identify the suitable areas for each crop. The results identified 397,720 km² of suitable areas for common oats of forage purpose distributed in 744 counties in 17 provinces, and 556,232 km² of suitable areas for naked oats of grain purpose distributed in 779 counties in 19 provinces. This result is in accordance with the distribution of farming-pastoral ecozones located in semi-arid regions of northern China. The mapped areas can help define the working limits and serve as indicative zones for oat in China. The created databases, mapped results, interface of expert system and relevant hardware facilities could construct a complete crop support system for oats.

Keywords: common oat, naked oat, multi-criteria evaluation, GIS; spatial database

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1. INTRODUCTION

Agriculture is the foundation of the national economy in China. Deterioration of ecological environment caused by poor management and unsustainable use of the natural resources has become a serious impediment to agricultural development particularly noticeable in the west of the country. Because of the tolerance to infertile, arid and salt environment, cultivation of common oat (*Avena sativa* L.) and naked oat (*Avena nuda* L.) can achieve the harmony and consolidation of production and improvement of the environment (Wang et al., 2006). Besides, common oat and naked oat have high nutritional values (CAMS, 1991; Zhang, 2006) and could be used for both grain and forage purpose. In China naked oat varieties dominate the cultivation of oat, particularly in the semi-arid farming-pastoral areas located northwest and northeast of the country, for the purpose of both grain and forage use. Only in some high-elevation regions in northwest and southwest plant common oat, generally for forage use (Li et al., 2007). It has become the main forage cultivated in the pasturing areas in west China to deal with the shortage of forage (Hou, 2003; Xu, 2003).

The identification of the suitable areas is essential to agricultural research and development (Corbett, 1996), it is an introduction for the future cultivation and programming of certain crops. Thus, in this study the suitable areas for common oat and naked oat in China should be identified. These tasks would provide visual guidance for the cultivation and the layout planning of oats in the future.

Suitable areas for crops are determined by evaluation of the climate, soil and topographical characteristics. Many variables and their criteria are involved in the analysis. Geographic information systems (GIS) are best suited for handling spatial data, with due consideration for the spatial variability for an efficient time and cost-effective evaluation (Ahamed et al., 2000). GIS has been applied in crop suitability evaluation in recent years (Gao, 2000). At present, Multi-criteria evaluation (MCE) has received renewed attention within the context of GIS-based decision-making (Pereira and Duckstein, 1993). It could be understood as a world of concepts, approaches, models and methods that aid an evaluation (expressed by weights, values or intensities of preference) according to several criteria. The integration of MCE problems within GIS could give more functionality to the user (Carver, 1991) and could help users to improve decision making processes. This method has been used in searching the best area for an infrastructure (like a plant, a commerce, etc.) and it has been illustrated as a powerful approach to land suitability assessments (Joerin et al., 2001). The application of GIS-based MCE in identify suitable areas for crops or fruit trees in a regional scale has been reported (Ceballos-Silva et al., 2003; Qiu et al., 2005).

However, the relevant research in identification of suitable areas for a certain crop such as oats in China hasn't been conducted. The objectives of this study were: (1) to establish the national space database of climate, topography and soil; (2) to research the suitable areas of common oat and naked oat within GIS and MCE approach at national scale, provincial scale and county scale in China.

2. METHODS

2.1 Establish of spatial databases

Climate data was obtained from China Meteorological Administration (CMA). The recorded years were 1970-2002. The variables selected were annual accumulated temperature, maximum temperature, minimum temperature, precipitation and sunlight duration. The climate data were obtained as point data, an interpolation procedure was conducted to estimate the spatial distribution of each climate variable. These works were conducted within the Ordinary Kriging model in the ArcGIS environment. Albers coordinate system was used, the spatial resolution was 1000m per pixel. The interpolated maps of accumulated temperature, maximum and minimum temperature were corrected by elevation (Corbett, 1996). First, regression models were carried out using temperature and altitude values from stations to get the temperature lapse rates (TLR) for each of the three factors, and then applied to each pixel of the interpolated temperature maps. The Mean Relative Error (MRE) of before and after adjust by elevation was calculated.

National digital contour map at the scale of 1:250 000 was obtained from the State Bureau of Surveying and Mapping. We use this contour data to create Digital Elevation Model (DEM) within ArcGIS, the process was contours→ TIN→ lattice → DEM. The slope and elevation information were obtained from the DEM. The Albers coordinate system was used, the spatial resolution was 1000m per pixel.

Soil characteristics were taken from digital Soil Type Maps (from ISSCAS) using a scale of 1:1 000 000. Sampling points was created, the total number of points were 99034. The information of soil texture and soil pH was obtained from soil type. Then the soil texture point data and the soil pH point data were interpolated into grid maps within ArcGIS. The Albers coordinate system was used and the spatial resolution was 1000m per pixel.

Land use information was taken from the digital land use maps of China (from Environmental and ecological Science Data Center for West China,

2000) at a cell size of 1000m. The land use type of urban use, residential areas, mining, water bodies and desert were excluded from the analysis as the non-suitable areas for crop cultivation.

2.2 MCE process for suitable areas of oats

The first phase of MCE consisted of the establishing of the relevant criteria for the analysis. By means of expert opinion and literatures, it was revealed that Accumulated Temperature, Maximum Temperature, Minimum Temperature, Precipitation, Sunlight Duration, Soil Texture, Soil pH, Elevation and Slope were the relevant factors for common oat and naked oat (Dong et al., 1994). Suitability levels for each of the factors were defined, these levels were used as a base to construct the criteria maps. According to the experts’ opinion and the literatures, a specific suitability level per factor for naked oat and common oat were defined (Tables 2 and Table 3). Standardized factor maps were then constructed for common oat and naked oat from the interpolated maps of the factors. Constraint maps including urban use, residential areas, mining, water bodies, and desert were also made.

Table 2. Suitability level per factor for common oat

Factor	Level of suitability				
	Very high	High	Medium	Low	Very low
Accumulated temperature (°C)	1400-2700	1000-1400 or 2700-3500	800-1000 or 3500-4000	500-800 or 4000-4700	<500 or >4700
Precipitation (mm)	450-650	400-450 or 650-800	350-400 or 800-1000	280-350 or 1000-1200	<280 or >1200
Max Temp (°C)	14-19	19-21 or 10-14	21-23 or 8-10	23-25 or 6-8	>25 or <6
Min Temp (°C)	2-7	-1-2 or 7-9	-3--1 or 9-11	11-14 or -4--3	<-4 or >14
Sun duration (h)	>2400	2100-2400	1900-2100	1700-1900	<1700
Soil texture	Loam	Sandy loam	Sandy clay loam	Other class	Sand or clay
Soil pH	5.5-6.5	6.5-7.5	7.5-8.5	8.5-9.0	<5.5 or >9.0
Elevation (masl)	2000-3400	3400-3700 or 1500-2000	1000-1500 or 3700--4000	4000-4500	>4500 or <1000
Slope (%)	0-3	3-8	8-15	15-25	>25

Table3. Suitability level per factor for naked oat

Factor	Level of suitability				
	Very high	High	Medium	Low	Very low
Accumulated temperature (°C)	2400-3500	2000-2400 or 3500-3900	3900-4300 or 1500-2000	1000-1500 or 4300-4700	<1000 or >4700
Precipitation (mm)	420-600	350-420 or 600-750	750-1000	250-350	<250 or >1000
Max Temp (°C)	17-20	20-23 or 14-17	23-25 or 12-14	25-27	>27 or <12
Min Temp (°C)	4-7	2-4 or 7-9	0-2 or 9-11	-2-0 or 11-14	<-2 or >14
Sun duration (h)	>2400	2100-2400	1900-2100	1700-1900	<1700
Soil texture	Loam	Sandy loam	Sandy clay loam	Other class	Sand or clay
Soil pH	5.5-6.5	6.5-7.5	7.5-8.5	8.5-9.0	<5.5 or >9.0
Elevation (masl)	1400-2200	1000-1400 or 2200-2500	<1000 or 2500-2700	2700-3000	>3000
Slope (%)	0-3	3-8	8-15	15-25	>25

Pair-wise comparison matrixes were made to get the weights of each factor for common oat and naked oat. The comparison concerns the relative importance of the two criteria involved in determining the suitability of the stated objective. This method use a scale with values from 1/9 to 9 to rate the relative preferences of the two criteria. In this study, factors were rated according to the opinion of crop experts from the Academy of Agricultural Sciences of Neimenggu and the Dry Farming Research Center of Dingxi.

Once the factors and constraints maps have been obtained, and the weights of each factor were calculated, the next step was to multiply each factor map by its weight and then sum the results. These works were conducted with the Weighted Overlay module in the ArcGIS environment. Next the summed map was overlaid with the Constraint maps to erase the non-suitable areas for crop cultivation, then the suitability map which has values in the same range as the standardized factor maps was produced.

Finally, the land use map and the maps of suitable areas for common oat and naked oat were crossed respectively. In this way, we obtained useful information concerning the spatial distribution of several suitability levels, according to Land use information.

3. RESULTS

3.1 Adjust of interpolated temperature maps by elevation

For accumulated temperature, the temperature lapse rates (TLR) was 1.12626 (°C/m⁻¹), R²= 0.57; for maximum temperature, the TLR was 0.0043 (°C/m⁻¹), R²= 0.88; for minimum temperature, the TLR was 0.0036 (°C/m⁻¹), R²= 0.75. The Mean Relative Error (MRE) between the measured (Z_{oi}) and the simulated value (Z_{ei}) of before and after adjust by elevation was calculated using the following formula (1) and the results showed in table 5.

$$MRE = \frac{1}{n} \sum_{i=1}^n \left| \frac{Z_{oi} - Z_{ei}}{Z_{oi}} \right|$$

(1)

Table 5. Mean relative errors (MRE) results of before and after adjust

	Maximum temperature	Minimum temperature	accumulated temperature
Before adjust	0.0438	0.4694	0.1160
After adjust	0.0279	0.0502	0.0667

According to [table 5](#), the Mean Relative Error of interpolation much decreased after adjusted by elevation. Therefore the adjusted temperature maps were used to obtain the standardized factor maps.

3.2 MCE process for common oat

Weights of factors for common oat were calculated based on the Pair-wise comparison matrixes. The most important factors for common oat were: Accumulated Temperature (0.3078), Precipitation (0.2732), and Elevation (0.1441); Minimum Temperature (0.0779), Maximum Temperature (0.0745) and Sunlight Duration (0.0536) followed; Soil pH (0.0263), Soil Texture Class (0.0255) and Slope (0.0171) were the factors with the least importance. The consistency ratio was 0.04, considered acceptable. Once the standardized factor maps ([Fig.1](#)) and the weights per factor were obtained, the MCE was carried out and the map of suitable areas for common oat was obtained, then it was overlaid by the provincial boundaries to facilitate observation of the map ([Fig. 2](#)).

According to [Fig. 2](#), Very high suitability areas were located in some mountain areas in Neimenggu, Hebei, Shanxi, Shaanxi, Gansu, Ningxia, Qinghai, Sichuan, Xinjiang and Xizang provinces. These areas generally had enough sunlight, cool weather, and without drought.

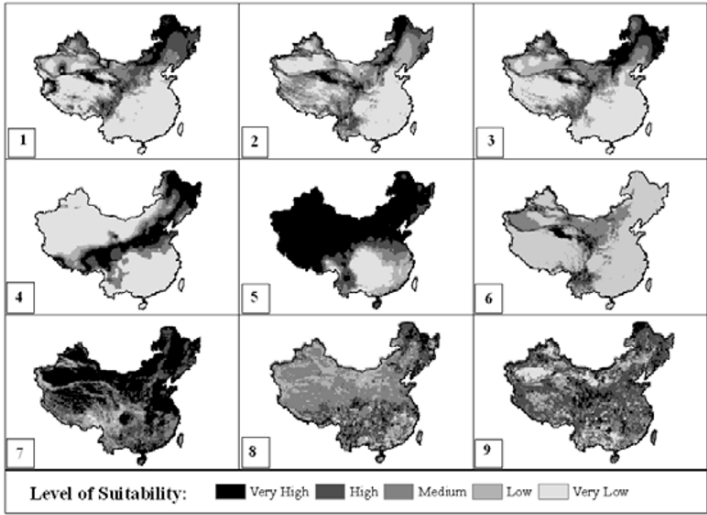


Fig.1: Factor map for common oat, including suitability levels for each factor. 1= Accumulated temperature, 2= Maximum temperature, 3= minimum temperature, 4= Precipitation, 5= Sunlight duration, 6= Elevation, 7= slope, 8= Soil pH, 9= Soil texture class.

The suitability map and the land use map were crossed and the extent of each suitability level per land use class was calculated ([Table 6](#)). The result identified

19,343 km² with very high suitability level and 378,377 km² with high suitability level in Dryland, these areas which totaled 397,720 km² can be considered as the best areas for common oat cultivation.

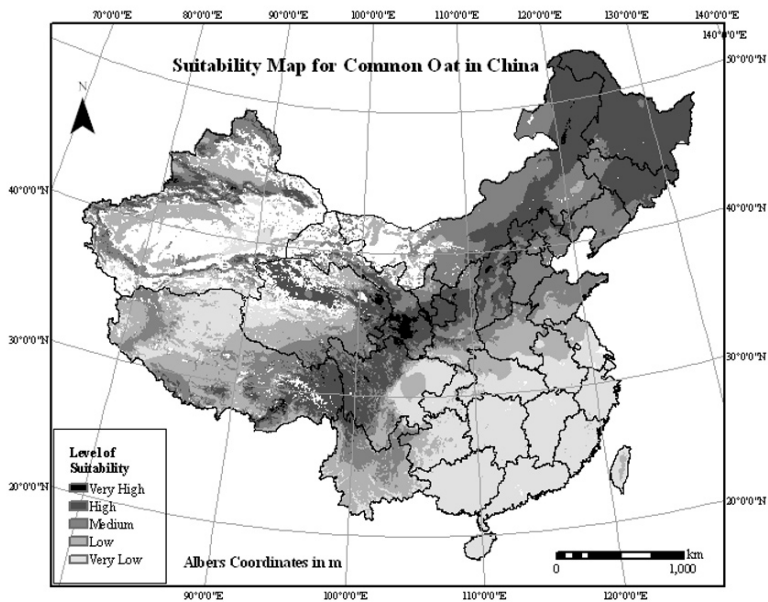


Fig.2: Suitability map for common oat in China.

Table 6. Result of crossing the suitability map for common oat and land use map.

Land use	Suitability level				
	Very high	High	Medium	Low	Very low
Pf	155 ^a	19892	27180	66432	353581
DI	19343	378377	467655	326092	237441
FI	40811	555173	188228	181954	463201
Sh	6301	91404	72728	79433	137201
Sp	4435	68990	62218	80716	324528
Hg	24255	360558	478059	274141	110051
Mg	24088	328421	424708	271086	143043
Lg	6816	106017	321726	213171	72589
Sa	2	30715	25871	32931	17344
MI	309	49346	17657	5677	517
BI	0	33127	24330	20485	765

^a Units are in square kilometers (km²). Pf = Paddy field, DI = Dry land, FI = Forest land, Sh = Shrub land, Sp = Sparse forest, Hg = High-coverage grassland, Mg = Moderate-coverage grassland, Lg = Low-coverage grassland, Sa = Saline-alkaline land, MI = Marshland, BI = Bare land.

After overlaying the results with the province and county boundaries, suitability maps for common oat in each province and each county were obtained. 744 counties in 17 provinces were identified as potential areas for planting common oat, and their areas were calculated. Suitable areas per land use type for each province were shown in [table 7](#), according to the result, Heilongjiang province has a largest potential area for common oat located in Dry land, Gansu, Jilin and Neimenggu province followed.

Table 7. Suitable areas for common oat in each province, take Gansu, Heilongjiang, Jilin, Neimenggu and Xinjiang province for example.

Province	Land use										
	Pf	DI	FI	Sh	Sp	Hg	Mg	Lg	Sa	MI	BI
Gansu	1	58064	17977	2868	3942	31659	32960	23448	35	494	62
Heilongjiang	10511	140498	169378	8746	30151	36206	5774	1702	2198	23194	10
Jilin	8147	52815	65839	1480	6394	2880	1306	262	1570	2269	72
Neimenggu	403	51724	138292	20227	5391	111403	49708	11976	1434	18344	48
Xinjiang	0	2505	11703	888	618	59478	41516	31496	53	928	1180

3.3 MCE process for naked oat

For naked oat, the weights of each factor were as follows: Accumulated Temperature (0.3124), Precipitation (0.2827), Minimum Temperature (0.0920), Maximum Temperature (0.0888), Elevation (0.0766), Sunlight Duration (0.0717), Soil pH (0.0289), Soil Texture (0.0285) and Slope (0.0184). The consistency ratio was 0.04, considered acceptable. Once the standardized factor maps ([Fig.3](#)), the constraint maps and the weights per factor were obtained, the MCE was carried out and the maps of suitable areas for naked oat were obtained ([Fig. 4](#)).

According to [Fig.4](#), very high suitability areas were located in some areas in Heilongjiang, Neimenggu, Jilin, Hebei, Shanxi, Shaanxi, Gansu, Ningxia and Xinjiang provinces.

The suitability map and the land use map were crossed and the extent of each suitability level per land use class was calculated ([Table 8](#)). The result identified 245,509 km² with very high suitability level and 310,723 km² with high suitability level in Dryland, these areas which totaled 556,232 km² can be considered as the best areas for naked oat cultivation.

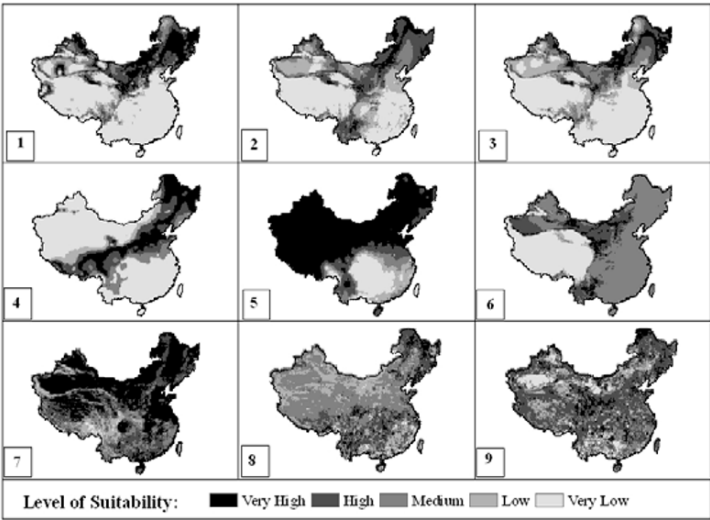


Fig.3: factor maps for naked oat, including suitability levels for each factor. 1= Accumulated temperature, 2= Maximum temperature, 3= minimum temperature, 4= Precipitation, 5= Sunlight duration, 6= Elevation, 7= slope, 8= Soil pH, 9= Soil texture class.

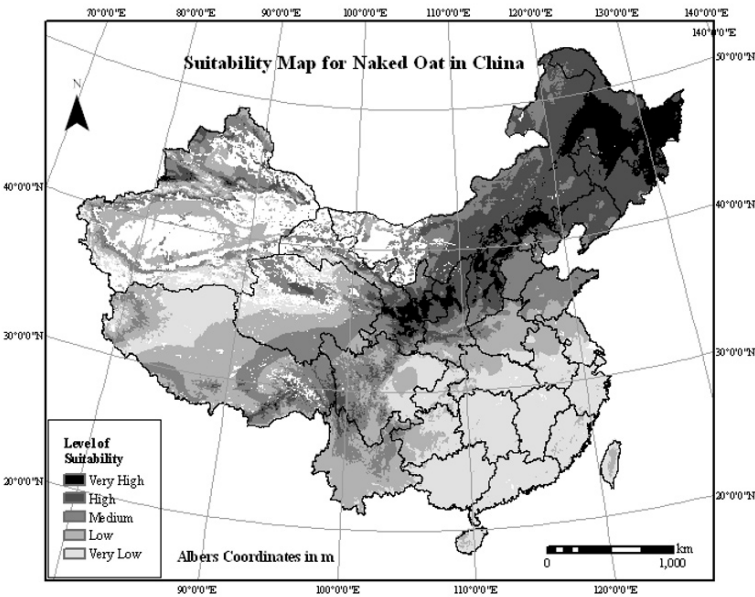


Fig.4: Suitability map for naked oat in China.

Table 8. Result of crossing the suitability map for naked oat and land use map.

Land use	Suitability level				
	Very high	High	Medium	Low	Very low
Pf	12993 ^a	21067	15156	81991	336033
DI	245509	310723	338309	319747	214620
FI	135534	434264	202782	240968	415819
Sh	28152	60325	67241	103576	118773
Sp	18348	63315	53685	107614	297925
Hg	60293	278848	405556	389848	112519
Mg	45193	254621	339814	355209	195800
Lg	17802	151231	269084	159064	122605
Sa	2057	25258	36966	39894	2688
MI	16185	39631	11952	5086	652
BI	7	6285	54738	15819	1839

^a Units are in square kilometers (km²).

According to Ministry of Agriculture of the PRC (www.agri.gov.cn, 2005), the area cultivated with naked oat in China was approximately 2,800 km², and most of the naked oat production areas were located in Dryland. However, our results showed 556,232 km² considered as very high and high suitability areas for that crop in Dryland. In China, many oat production areas were located in Saline-alkaline land, for example, oats were planted in Baicheng in Jinlin province for the amelioration of the Saline-alkaline soil. Our result also identified 27,315 km² as suitable areas for naked oat in Saline-alkaline land (Table 8).

After overlaying the results with province and county boundaries, suitability maps for naked oat in each province and each county were obtained. 779 counties in 19 provinces were identified as potential areas for planting naked oat, and their areas were calculated. Table 9 showed the suitable areas per land use type for each province, according to this result, Heilongjiang province has the largest suitable area for naked oat located in Dry land, Neimenggu, Jilin and Gansu province followed.

Table 9. Suitable areas for naked oat in each province, take Gansu, Heilongjiang, Neimenggu and Xinjiang province for example.

Province	Land use										
	Pf	DI	FI	Sh	Sp	Hg	Mg	Lg	Sa	MI	BI
Gansu	7	63532	16898	2125	3372	13780	19387	33504	163	114	1042
Heilongjiang	11045	144930	167318	8792	30122	38251	6496	2453	2629	23660	10
Jilin	8792	71261	72362	1824	8747	5882	3482	1220	7321	3953	104
Neimenggu	657	89649	123564	33928	6931	202388	128404	46023	8621	25363	1014
Xinjiang	26	8057	2600	933	787	12681	11002	50111	67	71	1424

4. DISCUSSION

In this research the spatial data input, extraction, analysis and visualization functions of GIS were used to establish the national spatial database of climate, topography and soil. The correction of interpolated temperature maps by elevation could improve the accuracy of our result. These could be useful for other researchers to interpolate different climate factors in China. MCE procedure in this research was useful to evaluate the suitable areas for certain crops. In this MCE, the factors were selected based on agronomic knowledge of local experts and reviews of existing literature. Factor maps should be independent and the expert opinion was important for the definition of suitability level. Pair-wise comparison matrixes in the context of Analytical Hierarchy Process were made to obtain the weights and confirmed to be a useful approach in the decision-making process. Crossing of identified suitability maps with the land use information was important. Land use information was used not only for the elimination of unsuitable land use types, but also for constraining the result in the suitable land use types and minimizing the conflicts over land use. The introduction of administrative boundaries in this research was a useful approach that allowed us to present our results at national, provincial and county scales. This three-scale result presentation can provide general alternatives to agricultural land management of specific crops and varieties, being useful to different decision-makers such as local farmers, local government and the central government.

Furthermore, the feedback process of checking the results by local agronomic experts was involved, because results could be adjusted in light of their experience.

The identified suitable area for common oat and naked oat showed a zonal trend from southwest to northeast of China, this corresponds with the actual distribution of existing oat plantation sites. Besides, we found that the suitable area for common oat and naked oat is roughly consistent with the distribution of farming-pastoral ecotone in northern China (CAAS, 1984; Zhao et al., 2002). This result has demonstrated common oat and naked oat as the appropriate crops for agricultural production as well as for the Grain-for-Green process in the semi-arid regions of China.

However, the identified variety-suitable areas were proposed at a theoretical maximum, the microclimate and microtopography of the specific areas should be considered in the actual production. Decision-making process to select adequate crop patterns could be based on other issues such as: production supports (by local and federal governments), marketing, technological level, economic evaluation, in addition to local cultural traditions, which are highly important also.

5. CONCLUSIONS

In this research, we applied the MCE approach to identify suitable areas for common oat with forage purpose and naked oat with grain purpose within a GIS environment. The results confirmed that the methodology used was adequate to construct and integrate spatial databases of climate, soil, topography and land use. The interpolated factor maps of temperature, precipitation, sunlight duration, elevation, slope, soil pH, soil texture class and land use information were crucial in the identification of suitable areas for oat-crop production. The results were presented at national, provincial and county scales. The involvement of local crop expert opinion allowed us to generate reasonable delineating conditions and to obtain reliable and consistent results. Expert system based on the research results will be constructed and connected with the internet to facilitate the work of decision-makers and farmers.

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STUDY ON SOIL NUTRIENT MANAGEMENT AND FERTILIZATION MODEL IN NINGXIA COUNTY TERRITORY WITH GIS

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Abstract: By adopting the GIS technology, this thesis tries to collect and recognize the existing pedological map, the soil nutrient graphic document and other related documents data of Ningxia. And with the classification and filtration to the material, the spatial databases and the attribute database can be established to combine the county territory soil nutrient data and the geography graph together to make the uninteresting form data visualized. Based on the soil nutrient database, the mathematical model is established by means of the design of the regression orthogonal combination. And Through the mathematical model optimization, the quantity of nitrophoskas which is employed at the maximum production rate as well as at the lowest can be obtained. With these, the paper proposes a model which can dispose, judge and analyze all the factors related to the fertilization to achieve the concrete formula and the amount of commonly used fat and the special-purpose compound fat. Therefore, the data analysis and the auxiliary decision-making enormously facilitate, and the automatization and the rationalization of all kind of crop's fertilization scheme in Ningxia can be realized.

Keywords: GIS, Soil nutrient; Fertilizer model, Goal output, Fertilizer parameter

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1. INTRODUCTION

For lack of the essential soil test facility, it is difficult to implement fertilization by soil test in some undeveloped area in China. Therefore, “the average suitability recommendation fertilization” arises at this historic background to characterize the technology of soil test and fertilizer recommendation with Chinese characteristic. With the statement of “the digital agriculture” concept, as well as the establishment of national soil and terrain digital database, based on the geographic information system(GIS), there massively appeared many fertilizer systems which have been recommended by experts(Wang et al., 1998). This research with the aid of the GIS spatial data managerial technique, the synthesis uses methods and so on spatial superposition, visualization to carry on the effective management to the Ningxia county territory soil nutrient data(Li et al., 2003; L. et al., 2003). And in this data foundation, in view of the Ningxia characteristic crops, the basis applies fertilizer balanced the theory, applies fertilizer the parameter with the aid of each kind, establishes the regression model, had determined commonly used fat and special-purpose compound fat applies fertilizer the plan; Established interactive, the intellectualized characteristic crops to apply fertilizer the software to instruct the farmer pointed qualitative, the quota to apply fertilizer, raised the fertilizer use factor, realized crops' high production, high quality, has achieved the low consumption, the highly effective goal.

2. MATERIALS AND METHODS

2.1 Soil nutrient data management

Take Visual c# and SuperMap Objects5 as the software development platforms to establish the Ningxia soil nutrient data management system which includes 1:50000 pedological map, the soil nutrient graphic document, the general detailed soil survey data and the attribute data. This system can be applied from the soil spatial data to the soil nutrient data management, the inquiry and the data search. Soil attribute database will display every soil nutrient target and its spatial databases in electronic map to demonstrate the variation rule of these nutrient targets.

2.1.1 Database establishment

According to different data format, the data may be partitioned as the spatial data and the attribute data. In this system the spatial data namely

refers to the description space position and the corresponding relational data, adopt the Ningxia Hui Autonomous Region 1:50000 topographic diagram to carry on the digitization, the spatial databases of the entire district can be obtained. Every soil space attribute (area, perimeter, name, code number, respective county territory and so on) can be put in the working space database table. The attribute data mainly refers to the soil attribute database, according to the system designing plan and the procedure need, to program the soil attribute database, establish the structure of the database, its field and the main line directs. Based on the general detailed soil survey investigation, the chemical examination analysis result and the N, P, K as well as the trace element correlation data from the Agriculture department, with the input of these soil attribute database, the soil attribute database's will relate to each soil nutrient target space data through the key field, to fully demonstrate these nutrient target in the electronic map in the spatial distributed situation.

2.1.2 Data inquiry and retrieval

The spatial data inquiry can be realized by SuperMap Objects 5 through options and soil land parcel, soil distribution as well as regionalism, the window browser which corresponds with the graphic data may be turned on to realize each kind of soil spatial data and the attribute data visualization graphic mode demonstration and according to the actual operation request to carry on the enlargement, the reduction, the migration and the return to original state to the electronic map. The inquiry and the search function of attribute data are completed by Visual c#, by clicking an essential factor of sampling point graph to demonstrate its attribute, this can also be got by using the sector selection tool, simultaneously chooses in the region which assigns many sampling points to extract and demonstrate after its statistical analysis the overall attribute, Its schematic diagram is shown in Fig.1

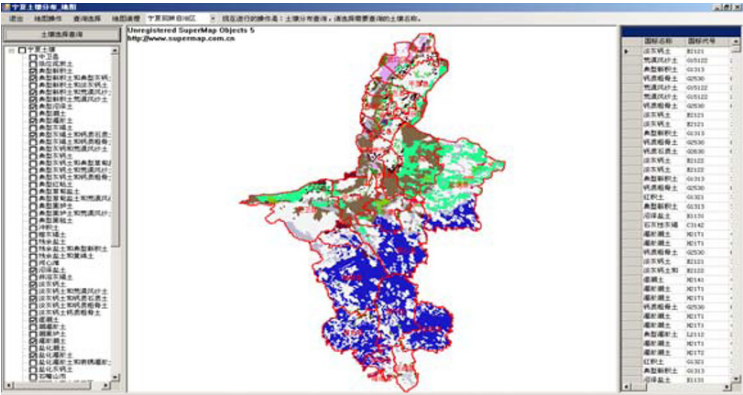


Fig.1: The distributing map of soil in Ningxia

2.1.3 Data maintenance and dynamic updating

In the crops growth process, influenced by many kinds of extraneous factors and the production actual need, the database momentarily must face the maintenance and the renewal question. The long-term agricultural cultivation will change the soil nutrient target, therefore the soil attribute database should renew the value, even increase or the reduced corresponding field suitably.

2.2 Fertilization model establishment

The soil quantity fertilizer's determination receives aspect and so on crops type and production level, soil type and for fat ability, fertilizer type variety and use factor, climate and agricultural technology syntheses affects(Hou et al., 2003). According to the establishment soil nutrient database, selects the Ningxia Hui Autonomous Region five characteristic crops: The wine-making grape, the Chinese matrimony-vine, the silkworm raising, the ma-huang, the licorice have established the regression model, this model mainly realizes applies fertilizer the formula automation, the rationalization, the core question is the soil nutrient, the fertilizer use factor as well as the crops needs the nutrient the parameter estimation, is as follows according to three Yuan two return orthogonal unitized design regression equation:

$$Y = a + bx_1 + Cx_2 + dx_3 + ex_1x_2 + fx_2x_3 + g x_1x_3 + h x_1^2 + i x_2^2 + j x_3^2 \quad (1)$$

And, x_1 is the nitrogen element demand (kg/hm^2), x_2 is the phosphorus element demand (kg/hm^2), x_3 is the potassium element demand (kg/hm^2), Y is the goal output (kg/hm^2), $a, b, c, d, e, f, g, h, i, j$ are the fertilizer field test regression equation coefficients, they change along with the different crops soil texture.

2.2.1 Fertilization quantity at maximum production rate

Disregard the product price, the nitrogenous fertilizer price, the phosphate fertilizer price and the potassium fertilizer price, just evaluate the regression equation (1) about x_1, x_2, x_3 first-order partial derivative and make them to zero, then the biggest fertilizer quantity under all levels of output foundation will be figure out and apply the fertilizer quantity to the formula, the maximum production rate is possible to obtain.

$$x_{N1} = \frac{-4bij - def - cfg + 2idg + 2cej + bf^2}{8hij + 2efg - 2ig^2 - 2je^2 - 2hf^2} \quad (2)$$

$$x_{P1} = \frac{-4chj - bfg - deg + cg^2 + 2bej + 2dfh}{8hij + 2efg - 2ig^2 - 2je^2 - 2hf^2} \quad (3)$$

$$x_{K1} = \frac{-4ihd - ceg - ebf + 2big + e^2d + 2hfc}{8hij + 2efg - 2ig^2 - 2je^2 - 2hf^2} \quad (4)$$

x_{N1} , x_{P1} , x_{K1} is the quantity of azote, phosphor and kalium at the maximum production rate, b , c , d , e , f , g , h , i , j is a coefficient.

2.2.2 Fertilization quantity for best economic efficiency output

When crops, nitrogenous fertilizer, phosphate fertilizer and potassium fertilizer unit price are known, revises the original regression model to be as follows:

$$L = Yp - x_1p_N - x_2p_P - x_3p_K \quad (5)$$

L is the real return, Y is the goal output (kg/hm^2), x_1 is the nitrogen, the phosphorus and the potassium element demand (kg/hm^2) respectively, p , p_N , p_P , p_K are the crops unit price, the nitrogenous fertilizer unit price, the phosphate fertilizer unit price and the potassium fertilizer unit price respectively. Substitutes (5) in the formula (1) type:

$$L = (a + bx_1 + Cx_2 + dx_3 + ex_1x_2 + fx_2x_3 + g x_1x_3 + h x_1^2 + i x_2^2 + j x_3^2)p - x_1p_N - x_2p_P - x_3p_K \quad (6)$$

according to the principle that the best quantity fertilizer should be equal to the marginal cost, the equation best quantity fertilizer as well as the best output may be obtained. Also namely evaluate (6) about x_1 , x_2 , the x_3 first-order partial derivative, and make it to zero.

$$x_{N2} = \frac{4ij(\frac{p_N}{p} - b) + gf(\frac{p_P}{p} - C) + ef(\frac{p_K}{p} - d) + f^2(b - \frac{p_N}{p}) + 2ej(c - \frac{p_P}{p}) + 2ig(d - \frac{p_K}{p})}{8hij + 2efg - 2ig^2 - 2je^2 - 2hf^2} \quad (7)$$

$$x_{P2} = \frac{fg(\frac{p_N}{p} - b) + 4hj(\frac{p_P}{p} - C) + eg(\frac{p_K}{p} - d) + 2ej(b - \frac{p_N}{p}) + g^2(c - \frac{p_P}{p}) + 2fh(d - \frac{p_K}{p})}{8hij + 2efg - 2ig^2 - 2je^2 - 2hf^2} \quad (8)$$

$$x_{K2} = \frac{ef(\frac{p_N}{p} - b) + eg(\frac{p_P}{p} - C) + 4hi(\frac{p_K}{p} - d) + 2ig(b - \frac{p_N}{p}) + 2hf(c - \frac{p_P}{p}) + e^2(d - \frac{p_K}{p})}{8hij + 2efg - 2ig^2 - 2je^2 - 2hf^2} \quad (9)$$

x_{N2} , x_{P2} , x_{K2} is the quantity of azote, phosphor and kaliumtime at the best output.

In the system, the crops goal output which is input must be smaller than the greatest output, otherwise the system will prompt the user to correct automatically. Moreover, the quantity fertilizer which calculates based on the above formula, if smaller than zero, it means there is no need apply fertilizer.

3. RESULT AND DISCUSSION

3.1 Formula Schemes for commonly used fat and special-purpose compound fat

3.1.1 Trace element demand computation

With the above established fertilizer applying model, the annual amount of crops nitrogen phosphorus potassium needed is possible to be obtained, to fully consider the influence of soil texture to the parameter of fertilizer applying, the annual demand for the trace element should be calculated too, which involves the zinc, the manganese, the copper, the iron and the boron, the calculation step as follows (take zinc as example):

(1) Selects soil type and the crop pattern, gain the soil parameter and the crops parameter from the corresponding database table.

(2) Calculates the annual demand of trace element (kg/hm²)

$$m=(Y*k/1000-0.15*n*q)/r \tag{10}$$

And m is the trace element zinc demand (kg/hm²), Y is the goal output (kg/hm²), k is 1000 kilograms output needs the nutrient (kg/hm²), n is the soil nutrient content (kg/hm²), q is the soil nutrient supply rate (kg/hm²), r is the fertilizer use factor.

3.1.2 The common chemical fertilizer nutrient provides situation

Table 1, Table 2 shows the the proportion of N 、 P 、 K and microelementin familiar fertilize separately

Table 1 the proportion of NPK in familiar fertilizer

	(NH ₄) H ₂ PO ₄	(NH ₄) ₂ HPO ₄	CO(NH ₂) ₂	NH ₄ HCO ₃	(NH ₄) ₂ SO ₄	Ca(H ₂ PO ₄) ₂ ·H ₂ O	CaCO ₃	K ₂ SO ₄	KCl
N	12%	18%	46%	17%	20%				
P	52%	46%				12%	43%		
K								50%	55%

Table 2 the proportion of microelement in familiar fertilizer

	ZnSO ₄	MnSO ₄	CuSO ₄	FeSO ₄	Na ₂ B ₄ O ₇ ·10H ₂ O	H ₃ BO ₃
Zn	40. 5%					
Mn		24. 6%				
Cu			25. 9%			
Fe				19%		
B					11%	17%

Because the fertilizer is numerous, according to the actual situation during the fertilizer apply different choice can be made, rests on the fertilizer which is provided, the nitrogen element not only contains in ammonium and two ammonium, moreover also contains in the urea, the ammonium carbonate and the ammonium sulfate; At the same time, the phosphorus element not only contains in ammonium and two ammonium, moreover also contains in the Pu calcium and the heavy calcium. How to solve the problem of the origin of nitrogen and phosphorus is rather difficult, in the article ammonium or two ammonium is supposed to act according to the actual situation in overall fertilizer proportion then the problem can be solved by evaluating the rate of the nutrient proportion contains in each hectare as well as the chemical fertilizer.

3.1.3 Realization of fertilization formula scheme

1) Commonly used fat formula

Based on the fertilizer employment's actual situation, may make the following choice: Ammonium and two ammonium two elect one, the urea, the ammonium carbonate, the ammonium sulfate three choose one, Pu calcium and the heavy calcium two elects one, solves the nitrogen, the phosphorus origin question by this, the potassium sulfate, the potassium chloride two elects one, solution potassium origin question. In trace element's origin question, the zinc, the manganese, the copper, the iron easy to solve, the borax and the boric acid two elect one, solution boron origin question.

2) Special-purpose compound fat formula

What is different from the commonly used fat formula: The urea, the ammonium carbonate, the ammonium sulfate three elect two, the Pu calcium and the heavy calcium all elect, but must consider the following parameter in the formula: Nitrogen, phosphorus, potassium proportion, trace element proportion, compound fat always available nutrient content, trace element content as well as additive level.

3.2 Application process

The model of the soil applies fertilizer in the application process, fully considers the soil texture to the soil parameter influence. The core question is the soil fertilizer applying ability, the fertilizer profitability and the estimation on nutrient needed by crops. Its step is:

(1) Take the electronic map as the basis, according to geography plan gain soil type and basic soil nutrient data, choice planter crops.

(2) Based on key field value system constructs the SQL inquiry sentence, found the corresponding record of the soil and the crops from the database (Gu et al., 2005).

(3) system automatically read the related parameter which the model needs from the database record, other parameters which inputs on the man-machine interaction graphical interface carries on the model computation together with the user, obtains the nitrogen, the phosphorus, the potassium as well as the trace element demand.

(4) Choose the fertilizer formula plan, obtains the common chemical fertilizer concrete employment quantity, the computed result dynamic demonstration on the graphical interface.

4. CONCLUSION

Based on the GIS Ningxia county territory soil nutrient data management as well as the establishment of fertilization formula scheme, the thesis fully considers the different crops' need, the fat requirement rule and the coordinated relations between different soil, overcame the general method that has used qualitative primarily applies fertilizer. To a great extent, it reduced certain blindness, managed for the Ningxia farmland soil nutrient and applies fertilizer the decision-making to provide effective technological means. Through the GIS farmland soil nutrient management, may facilitate the inquiry application, according to the farmland soil nutrient's condition and the difference, the possible arrangement planting plan and formulates and applies pointed strong technical and the cultivation management measure; The union soil nutrient, the crop pattern, the application applies fertilizer the model to carry on the crops fertilizer recommendation formula, will be advantageous in obtains reasonable output and the benefit, and is advantageous to the protection soil and the agriculture ecological environment. In the research, carries on with many test point cooperations applies fertilizer the experiment, and has carried on the big area promoted application. The practice proved that this software has the high precision and the promoted value in the application.

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EXTENSION EVALUATION MODEL OF LAND DESTRUCTION DEGREE IN MINING AREA AND ITS APPLICATION

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Abstract: Taking Renjiazhuang coal mine as the object of study, this paper carries on evaluation to destruction degree in this area by using extension theory and establishing evaluation extension model of land destruction in mining area. Results show that severe destruction area of collapse land in Renjiazhuang coal mine is 112.86hm², moderate destruction area is 372.27hm², light destruction area is 723.42 hm², spoiled land belongs to light destruction and its area is 7.09 hm². Our study provides evidence for making countermeasures in destruction land reclamation in mining areas, choosing reclamation technology and carrying on suitability evaluation, etc. It is proved that the extension theory is feasible in evaluation of land destruction in mining areas.

Keywords: extension theory, mining area, destruction, extension model, evaluation

1. INTRODUCTION

Coal mining can cause the surface subsidence, land erosion, secondary salinization, swamping, land desertification, decrease of crop yield, additional slope, cracks, etc. Land reclamation in mining areas may alleviate

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human-land conflict and improve the ecological environments of mining area and the [surrounding areas](#). While the land destruction evaluation may provide essential basis for formulating countermeasures of destruction land reclamation, choosing reclamation craft and carrying on the suitability evaluation, it is essentially a evaluation on [variation degree](#) of mining area land quality caused by exploitation, revealed the utilization scope and [capacity](#) of land ([Fabin Li et al., 2006](#)).

The defects of traditional evaluation methods are obvious. For example, they can't eliminate the contradictory or overlapping relationship when selecting indexes. In addition, most of them are based on points, which influence the accuracy and objectivity of evaluation ([Tao Guan et al., 2005](#)). However, the superiority of extension evaluation method is obvious because it is the rule and method that studies the extension possibility of things with the formalized model, often used in dealing with contradictory problems ([Wen Cai et al., 2000](#)). Meanwhile, it is based on interval, so its result draws closer to the reality. Many studies have applied this theory in many domains' evaluation studies, including rock mass side slope stability judgment([Zhiqiang Kang et al., 2007](#)), the decision-making evaluation toland development and reorganization project ([Tao Guan et al., 2005](#)), quantification evaluation to building damage ([Limin Liu et al., 2004](#)), classified recognition of harmful insects in stored grain ([Jinli Yuan et al., 2004](#)), rank evaluation to water quality ([Yong Ye et al., 2007](#)), etc. While in the aspect of destruction land evaluation in mining area, this theory's application is still a blank. The objective of this study is to apply the extension theory in land destruction evaluation in mining areas, establish the extension model and index system of land destruction evaluation in mining areas and carry on example analysis.

2. BASIC PRINCIPLES OF EXTENSION EVALUTION METHOD

Extension theory was put forward by [Cai et al. \(1983\)](#) through combining the matter-element theory with extension set. The research objects of extension are the contradictory problems in the objective world Research contents are the rules and methods of dealing with contradictory problems. A combination of extention theory with other domains' theories caused corresponding new knowledge and formed the application of extension. Based on extension theory, some extension methods have been developed such as matter-element extension method, matter-element shifting method and priority evaluation method. The combination of these methods with those in other domains formed corresponding extension engineering method,

which has been applied in economy, management, decision-making and process control (Wen Cai et al., 1998, 1999).

2.1 Matter-element

Matter-element is a triple composed of thing, characteristic and characteristic value of the thing. Its expression is $R = (\text{thing}, \text{characteristic}, \text{value}) = (N, c, V)$. The 2-element group composed of c and V is called characteristic element and its expression is $M = (c, V)$. The thing is the name of thing in matter-element theory and its expression is $I(N)$, The characteristic is the thing's characteristic of nature, function, condition, etc., and its expression is $V(c)$ or $V = (a, b)$.

2.2 Theory of extension set

The main content of extension set is to quantitatively describe thing's variability by establishing correlation function. Its basic pattern is defining the distance of point to interval firstly and then establishing correlation function and describing thing's variability by calculating. The following relationship can be got by supposing x is any point in real domain $(-\infty, +\infty)$ and $X = (a, b)$ is the real interval in this domain:

$$\rho(x, X) = \left| x - \frac{a+b}{2} \right| - \frac{1}{2}(b-a) \quad (1)$$

$\rho(x, X)$ is the distance of x to X . The distance of x to two intervals $X_0 = (a, b)$ and $X = (c, d)$ is expressed by $D(x, X_0, X)$. The equation of $D(x, X_0, X)$ is written as

$$D(x, X_0, X) = \begin{cases} \rho(x, X) - \rho(x, X_0) & x \notin X_0 \\ -1 & x \in X_0 \end{cases} \quad (2)$$

By supposing $X_0 = (a, b)$, $X = (c, d)$ and $X_0 \subset X$, the correlation function between them can be expressed by $K(x, X)$. The expression of $K(x, X)$ is

$$K(x, X) = \frac{\rho(x, X)}{D(x, X_0, X)} \quad (3)$$

2.3 Establishment of extension model

First, the value scope of each evaluation factor is determined. Next, correlation function is established to evaluate each index. Then they are combined to the weight of each factor of evaluation index set and finally used to determine the rank. The basic steps are as follows (see the details in the establishment of extension evaluation model of land destruction in mining areas): ①establishing matter-element model of segment field and classic field of system; ②establishing correlation function and calculate correlation degree; ③ establishing the model of matter-element to be evaluated; ④ Determining the weight of each evaluation index; ⑤ Determining the correlation degree of the thing to be evaluated; ⑥ Determining the rank of the thing to be evaluated.

3. ESTABLISHMENT OF EXTENSION EVALUATION MODEL OF LAND DESTRUCTION IN MINING AREAS

According to the basic principles of extension evaluation method, the extension evaluation model of land destruction in mining areas can be established by following steps.

①Establishing matter-element model of segment field and classic field of system

$$R_p = (P, c, v) = \begin{bmatrix} P & c_1 & v_{p1} \\ & c_2 & v_{p2} \\ & \dots & \dots \\ & c_n & v_{pn} \end{bmatrix} = \begin{bmatrix} P & c_1 & <a_{p1}, b_{p1}> \\ & c_2 & <a_{p2}, b_{p2}> \\ & \dots & \dots \\ & c_n & <a_{pn}, b_{pn}> \end{bmatrix} \quad (4)$$

The above is matter-element model of segment field of system, P in this formula is all the ranks of land destruction in mining areas, v_{pi} is all the values' scope of corresponding index c_i , that is the segment field $<a_{pi}, b_{pi}>$ of P .

$$R_{oj} = (N_{oj}, C_o, V_o) = \begin{bmatrix} N_{oj} & c_1 & v_{oj1} \\ & c_2 & v_{oj2} \\ & \dots & \dots \\ & c_n & v_{ojn} \end{bmatrix} = \begin{bmatrix} p & c_1 & <a_{oj1}, b_{oj1}> \\ & c_2 & <a_{oj2}, b_{oj2}> \\ & \dots & \dots \\ & c_n & <a_{ojn}, b_{ojn}> \end{bmatrix} \quad (5)$$

The above is matter-element model of classic field of system, N_{oj} is the rank criteria of land destruction in mining areas ($j = 1, 2, 3$ represent light,

moderate and severe destruction respectively), v_{oji} is all the values' scope of corresponding index c_i , namely the classic field $\langle a_{oji}, b_{oji} \rangle$.

②Establishing correlation function and calculating correlation degree

The correlation degree is the measurement of relevance between things and between factors. Its expression is as follows:

$$\begin{cases} K_{ji} = -\frac{\rho(v_i, v_{oji})}{|v_{oji}|} \\ K_{ji} = \frac{\rho(v_i, v_{oji})}{\rho(v_i, v_{pi}) - \rho(v_i, v_{oji})} \end{cases} \quad (6)$$

③Establishing the model of matter-element for evaluation

The evaluation data information obtained by detection, collection and analysis are represented by the matter-element R_o . x_i represents the concrete numerical values corresponding to the evaluation index of the unit to be evaluated, P_0 represents evaluation object.

$$R_o = \begin{bmatrix} P_0 & c_1 & x_1 \\ & c_2 & x_2 \\ & \dots & \dots \\ & c_n & x_n \end{bmatrix} \quad (7)$$

④Determining the weight of each evaluation index

This study uses the set-valued statistics method to determine the weight of each evaluation index. This method can reflect the objective reality reasonably and give proper consideration on both the fuzziness and subjective judgment factor in the evaluation. It operates quite simply and is easy to spread. Balachandra et al. (1995) put forward the principles of this method.

⑤Determining the correlation degree of each destruction rank of mining area land for evaluation.

According to the weight determined by step ④, after calculating correlation degree, its expression is as follows:

$$K_j(p_o) = \sum_{i=1}^n w_i K_j(x_i) \quad (8)$$

This formula represents destruction rank of mining area land to be evaluated and its degree.

⑥Determining the destruction rank of mining area land

If $K_{j_0} = \max_{j_0 \in \{1,2,3\}} K_j(p_0)$, the destruction rank of the unit to be evaluated belongs to j_0 .

4. APPLICATION EXAMPLE

Taken Renjiazhuang coal mine as an example, destruction degree evaluation to mining area land is introduced based on extension theory. Renjiazhuang coal mine is a new mine without production yet. In-situ investigation and the verification of Ningxia Hui autonomous region and the local land resources management section shows no destruction land such as crack and collapse caused by coal mine production at present .

4.1 Construction of index system and evaluation criteria

The mining process causes the destruction of land resources. Destruction type is different, therefore, evaluation index is also different. For example, the main type of destruction land is collapse and spoiled land. For collapse land, there will be some changes with the exploration of mine field macroscopically, e.g., collapse, crack and water accumulation, etc; The soil properties will also change microscopically, e.g., soil nutrient. Correspondingly, For spoiled land, there will also be certain change. To evaluate the degree of land destruction accurately, we should choose indexes that can reflect destruction degree of mining area land directly or indirectly reasonably.

Table 1. Evaluation indexes of land destruction in mining areas and criteria

Destruction type	evaluation factor	evaluation factor	evaluation rank		
			I	II	III
collapse land	surface deformation	collapse depth	>50cm	50~200cm	>200cm
		collapse area	<100m ²	100~1000m ²	>1000m ²
		side slope degree of collapse	<25°	25°~35°	>35°
	surface crack	crack width	10cm	10~30cm	30cm
		crack spacel	>50m	30~50m	<30m
	soil properties	soil erodibility	<10%	10%~30%	>30%
		soil salinization	none	salinization	saline soil
		decline of soil fertility	<15%	15%~40%	>40%
	hydrological condition	status of water accumulation	none	seasonal	long-term
	stability	stability	stable	comparatively stable	unstable
pressure occupied land	surface change	spoiled area	<10000m ²	10000~50000m ²	>50000m ²
		side slope degree	<25°	25°~35°	>35°
	properties Of pressure occupied land	increase of gravel content	<10%	10%~30%	>30%
		decline of organic content	<15%	15%~65%	>65%
		pollution of toxic element	light	moderate	severe
		pH	6.5~7.5	4~6.5 7.5~8.5	<4,>8.5
	stability	stability	stable	comparatively stable	unstable

Considering Renjiazhuang coal mine’s actual situation and combining to general requirements of choosing indexes, we choose corresponding indexes

(Table 1).According to < Land Management Law of the People's Republic of China > in 2004 and < Land Reclamation Regulations of the State Council > in 1998, Evaluation rank of mine land's destruction degree is devided into 3-level criterion: level I (light destruction); level II (moderate destruction); level III (severe destruction).

4.2 Division of evaluation unit

The evaluation unit is the special object whose natural attribute and socio-economic attribute of land is basically consistent. It is the land unit that has special characteristics and the basic area used in charting. Its basic requirements of division is: (1)the properties in the unit are relatively homogeneous or close; (2)there are differences between units, it reflects the differences of land in certain time and space objectively; (3)the units should have certain comparability. The land resources in mining area have the particularity, its evaluation area is relatively small and the soil type and the land utilization type are relatively consistent. So the division of evaluation unit of destruction land in mining area is mainly based on destruction type. At the same time, we should give proper consideration to the basic consistency of land characteristics and utilization direction of reclamation and improvement ways in the same evaluation unit type.

Because the area of spoiled land is small and its properties are relatively simplistic, we take its whole as an evaluation unit. We use overlap method to divide the evaluation unit in collapse land. Here is the detail: take land utilization map of the mining area as base map, according to the destruction prediction of mining area, draw the distribution map of dominant factors (collapse depth, surface crack e.g.) that reflect the destruction degree, at last, by overlapping forms small polygons and by merging forms evaluation unit (see fig. 1).



Fig.1. Evaluation unit map of destruction land in Renjiazhuang mining area

4.3 Determine the segment field and classic field of evaluation indexes

The determination of upper limit and lower limit of segment field should depend on experts’ experiences, that is experts give the maximum values and minimum values of each indexes. Because the field of each index is not all the same, Smaller the values of some evaluation indexes are, higher their destruction ranks are (crack interval), Bigger the values of some evaluation indexes are, higher their destruction ranks are, we deal with each index with normalization and non-dimension (Qiuji Chen et al., 2006). Thus , according to table 1, we can determine the segment field and classic field of evaluation indexes as in table 2.

Table 2. Classic field and segment field of evaluation indexes

Destruction Type	Evaluation Factor	Evaluation Factor	Classic Field			Segment Field
			I	II	III	
Collapse Land	surface deformation	collapse depth	0~0.14	0.14~0.42	0.57~1	0~1
		collapse area	0~0.05	0.05~0.50	0.50~1	0~1
		side slope degree of collapse	0~0.36	0.36~0.50	0.50~1	0~1
	surface crack	crack width	0~0.20	0.20~0.60	0.60~1	0~1
		crack spacel	0.30~0.50	0.50~0.70	0.70~1	0.30~1
	soil properties	soil erodibility	0~0.17	0.17~0.50	0.50~1	0~1
		soil salinization	0.10~0.30	0.30~0.70	0.70~1	0.10~1
		decline of soil fertility	0~0.17	0.17~0.44	0.44~1	0~1
	hydrological condition	status of water accumulation	0.10~0.30	0.30~0.70	0.70~1	0.10~1
	stability	stability	0.10~0.30	0.30~0.70	0.70~1	0.10~1
Pressure Occupied Land	surface change	spoiled area	0~0.01	0.01~0.1	0.1~1	0~1
		side slope degree	0~0.33	0.33~0.47	0.47~1	0~1
	properties Of pressure occupied land	increase of gravel content	0~0.17	0.17~0.50	0.50~1	0~1
		decline of organic content	0~0.16	0.16~0.68	0.68~1	0~1
		pollution of toxic element	0.10~0.30	0.30~0.70	0.70~1	0.10~1
			0.25~0.35	0.35~0.6 (acid condition)	0.60~1 (acid condition)	0.25~1
		pH	0.46~0.53	0.53~0.61 (alkalinity condition)	0.61~1 (alkalinity condition)	0.46~1
		stability	0.10~0.30	0.30~0.70	0.70~1	0.10~1

4.4 Data processing

The data in the example are the various indexes’ prediction values of each evaluation unit, including the values of collapse land and spoiled land. The details are as in table 3 and table 4. Because of the length limit, only the values of some units are listed .

Table 3. Prediction values of indexes in collapse land of some evaluation units

evaluation unit	x ₁ (cm)	x ₂ (m ²)	x ₃ (°)	x ₄ (cm)	x ₅ (m)	x ₆ (%)	x ₇	x ₈ (%)	x ₉	x ₁₀	Area(hm ²)
1	101.5	1060	53.2	39.5	43	41.4	none	66.6	seasonal	unstable	7.25
2	31.5	320	18.9	10.5	55	12	none	10.8	seasonal	stable	46.94
3	14	1520	13.3	15.5	38	9	none	11.7	seasonal	stable	147.01

Note: x₁:collapse depth,x₂:collapse area,x₃:side slope degree of collapse,x₄:crack width,x₅: crack space ,x₆:soil erodibility ,x₇:soil salinization,x₈:decline of soil fertility ,x₉:status of water accumulation,x₁₀:stability.

Table 4. Prediction values of indexes in spoiled land

evaluation unit	x ₁ m ²	x ₂ °	x ₃	x ₄ (%)	x ₅	x ₆	x ₇	area hm ²
1	7.09	70	13.2	14.25	light	4.8	stable	7.09

Note: x₁:spoiled area ,x₂:side slope degree ,x₃:increase of gravel content ,x₄: decline of organic content,x₅: :pollution of toxic element ,x₆:pH ,x₇:stability.

By processing the data in table 3 and table 4 with normalization and non-dimension, we get the data shown in table 5 and table 6.

Table 5. Prediction values of indexes in collapse land of some evaluation units

evaluation unit	x ₁	x ₂	x ₃	x ₄	x ₅	x ₆	x ₇	x ₈	x ₉	x ₁₀
1	0.29	0.53	0.76	0.79	0.57	0.69	0.27	0.74	0.15	0.82
2	0.09	0.16	0.27	0.21	0.45	0.20	0.26	0.12	0.24	0.27
3	0.04	0.76	0.19	0.31	0.62	0.15	0.23	0.13	0.11	0.26

Note: the meaning of the symbols in the table is the same with in table 3

Table 6. Prediction values of indexes in spoiled land

evaluation unit	x ₁	x ₂	x ₃	x ₄	x ₅	x ₆	x ₇
1	0.71	0.93	0.22	0.15	0.22	0.52	0.15

Note: the meaning of the symbols in the table is the same with in table 4

4.5 Establishment of matter-element to be evaluated model

The data of an evaluation unit in a certain collapse land were got. Collapse depth is 101.5cm, collapse area is 1060m², side slope degree of collapse is

53.2°, crack width is 39.5cm, crack space is 43m, soil erodibility is 41.4%, there is no salinization in soil, decline of soil fertility is 66.6%, and seasonal water accumulation is unstable. We get the matter-element model of the unit to be evaluated with normalization and non-dimension as follow.

$$R_o = \begin{bmatrix} P_0 & c_1 & 0.29 \\ & c_2 & 0.53 \\ & c_3 & 0.76 \\ & c_4 & 0.79 \\ & c_5 & 0.57 \\ & c_6 & 0.69 \\ & c_7 & 0.27 \\ & c_8 & 0.74 \\ & c_9 & 0.15 \\ & c_{10} & 0.82 \end{bmatrix}$$

The same as above,we get the matter-element models of the other 14 units of collapse land and spoiled land to be evaluated. Because of the limit of space, we leave them out.

4.6 Evaluation process

①According to formula(5), we can get the values of correlation function shown in table 7 and table 8. The tables just show the results of a certain collapse land and spoiled land. We leave out the values of other units because of space.

Table 7. Correlation function values of indexes' ranks in collapse land

Value of correlation function	x ₁	x ₂	x ₃	x ₄	x ₅	x ₆	x ₇	x ₈	x ₉	x ₁₀
K ₁	-0.28	-0.49	-0.50	-0.59	-0.12	-0.54	0.25	-0.67	0.10	-0.73
K ₂	0.21	-0.04	-0.36	-0.18	0.15	-0.24	0.25	-0.52	-0.90	-0.37
K ₃	-0.60	0.04	0.36	0.18	-0.43	0.24	0.75	0.48	-0.97	0.37

Note: the meaning of the symbols in the table is the same with in table 3

Table 8. Correlation function values of indexes' ranks in spoiled land

Value of correlation function	x ₁	x ₂	x ₃	x ₄	x ₅	x ₆	x ₇
K ₁	-0.71	-0.90	-0.19	0.06	0.40	-0.39	0.25
K ₂	-0.68	-0.87	0.15	-0.06	-0.40	0.32	-0.75
K ₃	0.32	0.13	-0.56	-0.78	-0.80	-0.23	-0.92

Note: the meaning of the symbols in the table is the same with in table 4

②Determine the weight of each evaluation index

We use the set-valued statistics method to get the weight of each evaluation index as follows.

$W_{collapse}=\{0.18,0.17,0.11,0.09,0.07,0.03,0.03,0.03,0.14,0.15\}$

$W_{pressure}=\{0.03,0.26,0.10,0.06,0.19,0.13,0.23\}$

③ Determination of the correlation degree of evaluation unit and judgment of destruction rank

Taking a certain evaluation unit of collapse land as an example, according to formula (7), we can get the correlation degree about 3 levels—light destruction, moderate destruction and severe destruction. They respectively are-0.37、 -0.21 and -0.11. $K_{j0} = \max_{j_0 \in (1,2,3)} K_j(p_0) = -0.11$, so the rank of this evaluation unit belongs to severe destruction. Likewise, we can determine the destruction rank of spoiled land and other evaluation units of collapse land.

According to the above process, it can be predicted that in Renjiazhuang coal mine the mining will cause light destruction area 723.42 hm², moderate destruction area 372.27hm² and severe destruction area 112.86hm². Spoiled land belongs to light destruction and its area is 7.09hm². The distribution of destruction rank in this mining area is showed in fig. 2. This evaluation result may provide favourable evidence for formulating countermeasure of destruction land reclamation, choosing reclamation craft and carrying on the suitability evaluation.

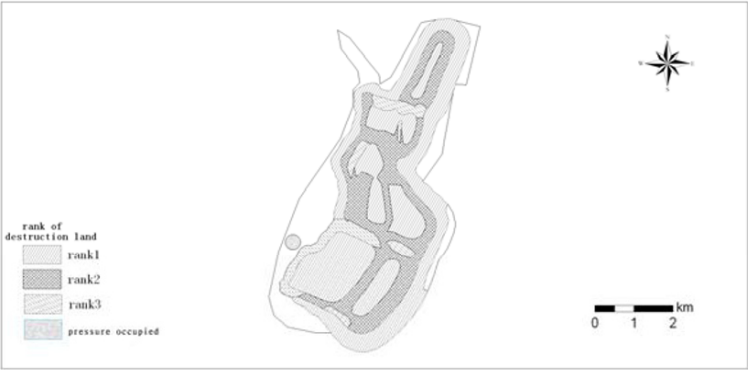


Fig.2. predicted map of land destruction situation of Renjiazhuang coal mine

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DYNAMIC SIMULATION MODEL FOR PRODUCTION AND DRY MATTER ACCUMULATION IN PEANUT

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Abstract: On the base of the physiological processes and according to the balance of the carbon, a simulation model for photosynthetic production and dry matter accumulation was established for the peanut. The photosynthesis rate of unit green leaf area was scribed by negative exponential function. By analyzing the characteristic of the shoots, the Gaussian integration method was used to calculate the photosynthesis for each period of time, and the daily total canopy photosynthesis which was that of all day. The effects of physiological age, temperature and water deficit factors on maximum photosynthesis rate were adequately quantified. The maintenance respiration and growth respiration was considered in the model which consume some photosynthetic. The computer was used to simulate the progress. The model was tested for dry matter accumulation by the field experiments of different genotypes and water levels and the results showed a good fit between the observed and simulated data. The present model appears to be favorable on mechanism explanation and reliable prediction.

Keywords: Peanut; Photosynthesis; Dry matter accumulation; Simulation model

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1. INTRODUCTION

Using the information technology to simulate the growth situation of the crops is a new research field and springs up in the last thirty or forty years. It combines the information technology and the agricultural technology and brings a profound and extensive influence to the traditional agricultural technology and production. Crop growth simulation is a synthetical and basic research field; it includes agronomy, aerography, botany and agrology and so on. The simulation model is the research keystone of this subject (Wang Yali *etal*, 2005). The mechanism, system and currency are its characters. Researchers for China or abroad have done lot of work in this way at present especially the Netherlandish and the American scholars(de Wit C.T. *etal*, 1970; Ritchie J.T.,1972;de Wit C.T. *etal*, 1978; van Keulen H, 1982; Ritchie J.T.,1997;Yan Lijiao *etal*, 1998).

Peanut is usually planted as oil and economic plants, so the growth area is small and the growth region is narrow in a certain extent. And this situation leads to people do little research in the model simulation of peanut(Duncan *etal*,1974; Young *etal*,1979; Ingram *etal*,1981). Compared with wheat, rice and so on, the research did in China was also little, but in China peanut plays an important role in the economic development and agricultural production. So on the base of the work has done in China and abroad, the simulation on peanut was did. In this project, the radicalization, temperature, moisture and other factor were all considered synthetically. The relation ship between the photosynthesis rate and circumstance was affirmed; the parameter in this model was selected. The dry matter accumulation model was set fit to the climate of China.

2. MATERIAL AND METHOD

2.1 Experimental place

The peanut was planted in the southeast area of Pangge village in Daxing district of Beijing. The soil type of this area was sandy loam. The average dry density was 1.38g/cm^3 : the total nitrogen was 0.058%; the average N, P, K contents were 0.005%, 0.002% and 0.013% separately; the soil organic matter content was 0.95%. Hence this land was suitable to plant peanuts.

2.2 Experimental design

The field blocks were designed by two factors; one was the soil water condition and the other was breed. To reach the designed water conditions, the blocks were covered with plastic shed when it rained at the stages of flowering and pod-setting during peanut growth. To prevent water diffuse, plastic membranes were buried surrounding each plot for 2m in depth. The seeds were planted in the middle of May in 2006 and harvested in the middle of September. The size of each sub plot was 2.1m×2.0m, and repeated 3 times. The seeding method was hill-drop. The hill spacing was 20cm, row spacing was 35cm.

3. MODEL ESTABLISH

3.1 Calculate of the total radiation

Based on the equation of Angstrom, according the percent of sunlight, the quantity of radiation was got, and it was input to the model as the primal variable. The expression was followed as this:

$$Q(t) = Q_0(t) \times [a + b \times \frac{dSUNH}{DL(t)}] \quad (1)$$

Parameter meaning: $Q(t)$ -the numerical value of total radiation ($Jm^{-2}d^{-1}$); $Q_0(t)$ -the numerical value of chronometer radiation; $dSUNH$ -the sunlight hour(h); $DL(t)$ -length of daytime; a and b -the parameter of mode.

3.2 The calculation of available radiation in the shoots

Use the method of Gauss integral to calculate daily available radiation, the particular calculational expressions was below:

$$PAR[i] = 0.5 \times Q(t) \times SINB[i] \times (1.0 + 0.4 \times SINB[i]) / DSINBE \quad (2)$$

Parameter meaning: $PAR[i]$ -the available radiation in the i time ($Jm^{-2}s^{-1}$); $SINB[i]$ -the sine value of altitude solar; $Th[i]$ -the sun time(h); $DIS[i]$ -the distance in Gauss equation.

3.3 The distribute and absorb of the sunlight in the shoot

On the suppose of the leaves were all equality medium and with the formula of Lambert-Beer(Marcelis L.F.M.,1998)in1953 and Monsi-Seak formula(Penning de Vries,1982) the available radiation in the shoots can be got:

$$I_L [i] = (1 - \rho [i]) \times PAR [i] \times e^{-K [i] \times LAI} \quad (3)$$

Parameter meaning: K[i]-the extinction coefficient of the shoot; $\rho[i]$ - the reflectivity rate of the shoot; LAI- the index of the leaf area.

3.4 The establish of the photosynthesis model

Use minus exponential model to express the single leaf photosynthesis

$$PS [i] = P_{a \max} \times [1 - EXP (-EFF \times I_L [i] / P_{a \max})] \quad (4)$$

Parameter meaning: PS[i]- the photosynthesis rate of single leaf ($\text{kgCO}_2\text{hm}^{-2}\text{h}^{-1}$); $P_{a \max}$ -the maximum photosynthesis rate of single leaf ($\text{kgCO}_2\text{hm}^{-2}\text{h}^{-1}$); EFF-the primal utilize efficiency of the sunlight; $I_L[i]$ - the available radiation that absorbed in the i time.

The affect of temperature

Based on the existence research result (Liu Tiemei etal,2003), the sine function was use to correct the photosynthesis model:

$$f(T) = \begin{cases} 0 & T < T_0 \text{ or } T > T_{\max} \\ \sin[(T - T_0) / (T_{ol} - T_0) \times \pi / 2] & T_0 \leq T \leq T_{ol} \\ 1 & T_{ol} \leq T \leq T_{ou} \\ \cos[(T - T_{ou}) / (T_{\max} - T_{ou}) \times \pi / 2] & T_{ou} \leq T < T_{\max} \end{cases} \quad (5)$$

Parameter meaning: T-the daily temperature($^{\circ}\text{C}$); T_0 -the basic temperature($^{\circ}\text{C}$); T_{ol} -the floor level of optimum temperature($^{\circ}\text{C}$); T_{ou} -the upper limit of optimum temperature($^{\circ}\text{C}$); $T_{\max}$ - the maximum temperature($^{\circ}\text{C}$).

The affect of water

Usually the soil water content will change with the variety of rainfall, evaporation and soil factor, so the photosynthesis model should be amended (Liu Tiemei etal,2001; Jiang Qingzhen etal,1999):

$$f(W) = \begin{cases} 0 & W_t < W_p \\ (W_t - W_p) / (W_2 - W_p) & W_p \leq W_t \leq W_2 \\ 1 & W_2 \leq W_t \leq W_3 \\ 0.5 + 0.5 (W_t - 1) / (W_3 - 1) & W_t > W_3 \end{cases} \quad (6)$$

Parameter meaning : W_t -the average soil water constant of 0-80cm ; W_p -Wilting Point; W_2 -the floor level of optimum water; W_3 -the upper limit of optimum water.

The affect of physiological age

The formula to calculate the affect of physiological age was as follow:

$$f(A) = \begin{cases} 1 & PDT \leq 28 \\ EXP[-\lambda \times (PDT - 28)] & PDT > 28 \end{cases} \quad (7)$$

Parameter meaning: PDT-the number of growth days of peanut; λ -the coefficient of the curve.

The instantaneous photosynthesis speed of total shoots

$$TPS[i] = PS[i] \times LAI \quad (8)$$

Parameter meaning: TPS[i]-The instantaneous photosynthesis speed of total shoots ($\text{kgCO}_2\cdot\text{hm}^{-2}\cdot\text{h}^{-1}$)

The daily photosynthesis speed of total shoots

$$DTGA = \left[\left(\sum_{i=1}^3 TPS[i] \times WGUSS[i] \right) \times DL \right] \quad (9)$$

3.5 Respiration of the shoot

The model of photorespiration

$$RP = DTGA \times R_p(T_0) \times Q_{10}^{\frac{T-T_0}{10}} \quad (10)$$

The model of dark-respiration

Consult the research result of Penning de Vries, Marcelis (Marcelis L. F.,1993; Marcelis L.F.M) abroad and W X Cao, T M Liu, H J Wang in China, the dark-respiration was calculated:

$$RD = RG + RM \quad (11)$$

Parameter meaning: RD-dark-respiration consumption ($\text{kgCO}_2\cdot\text{hm}^{-2}\cdot\text{d}^{-1}$); RG-growth respiration ($\text{kgCO}_2\cdot\text{hm}^{-2}\cdot\text{d}^{-1}$); RM- maintenance respiration ($\text{kgCO}_2\cdot\text{hm}^{-2}\cdot\text{d}^{-1}$).

(a) The calculate of RM ($\text{kgCO}_2\cdot\text{hm}^{-2}\cdot\text{d}^{-1}$)

$$RM = R_m(T_0) \times Q_{10}^{\frac{T-T_0}{10}} \times W(t) \quad (12)$$

(b) The calculate of RG ($\text{kgCO}_2\cdot\text{hm}^{-2}\cdot\text{d}^{-1}$)

$$RG = R_g \times (DTGA - RM) \quad (13)$$

3.6 The dry matter accumulation model

With the balance of photorespiration and dark-respiration, the crop grown Based on the principle of conservation of mass and conservation of energy, the daily total photosynthesis was calculated:

$$PN = DTGA - RD - RP$$

(14)

Parameter meaning: PN- the daily total photosynthesis (kgCO₂·hm⁻²·d⁻¹).

$$\Delta W = \lambda \times \beta \times PN / (1 - \varepsilon)$$

(15)

Parameter meaning: ΔW-the increment of daily dry matter (kgm⁻²d⁻¹);
λ,β,ε-the coefficient.

The expressions of dry matter accumulate of the peanut:

$$W(t + 1) = W(t) + \Delta W$$

(16)

4. THE PRIMARY TEST OF MODEL

Five breed of peanut and two water condition were used to test the model. Take the RMSE and RE way to test the gap between the simulated value and observational value. The detail value was shown in [table 1](#).

Table1 The compare between simulated value and observational value

Treatment	water condition	sampling time				
		06-6-21	06-7-6	06-8-4	06-8-28	06-9-14
		RE				
Treatment I	normal	4.36	1.29	0.5	0.04	0.11
	stress	4.99	0.85	0.11	0.05	0.06
Treatment II	normal	1.87	0.8	0.43	0.10	0.14
	stress	3.13	0.50	0.18	0.08	0.06
TreatmentIII	normal	0.57	0.19	0.22	0.19	0.24
	stress	3.31	0.24	0.21	0.10	0.09
TreatmentIV	normal	2.25	1.21	0.46	0.02	0.02
	stress	3.70	0.97	0.17	0.02	0.00
CK	normal	0.75	0.34	0.04	0.21	0.22
	stress	2.61	0.30	0.34	0.22	0.16
average RE	normal	1.96	0.77	0.33	0.11	0.15
	stress	3.55	0.57	0.20	0.09	0.07
RMSE	normal	399.89	142.66	97.78	72.14	69.46
	stress	506.26	117.77	67.47	72.20	73.30

Seen from [table 1](#), the maximum average RE under the normal water condition and the stress condition was 1.96, and the RMSE was little than 399.89kg/hm⁻². The maximum average RE under the stress condition was 3.55, and the RMSE was little than 506.26 kg/hm⁻². The data were also showed that, when used this model to simulate the accumulate process of the peanut; the error was bigger in the early period than in the following period. With days going on the error became small gradually.

The equation of y=x in figure 1 means that the simulated value and were totally accord. So the near the distance of the point to the line, the small of the error was.

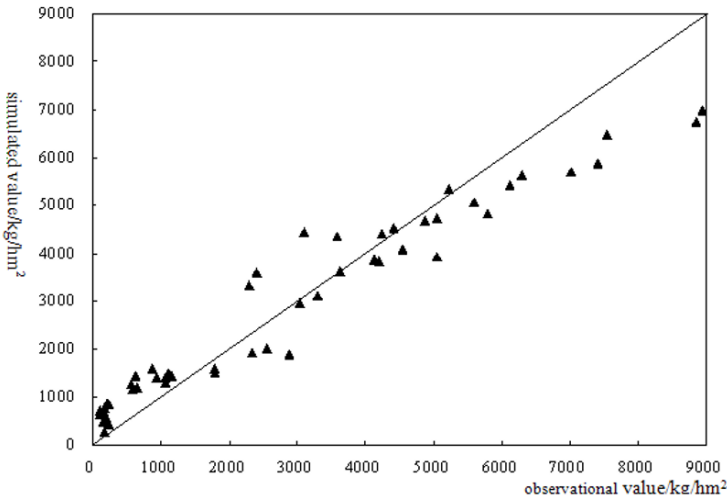


Fig.1 Compare of the observational value and the simulated

Results of [table 1](#) and [figure1](#) showed that in the early age of the peanut the error was large, but through the whole growth period, the model can simulate the simulation process of the dry matter exactly. This model had preferable forecast and applicability.

5. CONCLUSIONS

Based on the conservation of mass, conservation of energy, aerography and botany, the dry matter accumulation model of peanut was found. The results showed that this model had preferable forecast and applicability. Compared with the peanut simulation model before, this model had advanced in the following ways. Firstly, the Gaussian integration method was used to calculate the photosynthesis for each period of time, and the daily total canopy photosynthesis which was that of all day. Secondly, the effects of physiological age, temperature and water deficit factors on maximum photosynthesis rate were adequately quantified. Thirdly, by analyzing the characteristic of the shoots, the maintenance respiration and growth respiration was considered in the model. Tested by the field experiments of different genotypes and water levels in 2006, the results showed a good fit between the observed and simulated data. The present model appears to be favorable on mechanism explanation and reliable prediction.

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AUTOMATED DIGITAL IMAGE ANALYSES FOR ESTIMATING PERCENT GROUND COVER OF WINTER WHEAT BASED ON OBJECT FEATURES

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Abstract: Percent ground cover of vegetation is an important parameter for crop management. An innovational method based on features of objects was presented to automatically estimate percent ground cover of winter wheat from digital image analyses. Based on the features of wheat and its background components, an algorithm was designed to extract the percent ground cover, and the corresponding program was developed. This method was simple, labor-and time-saving with high classification accuracy about 90%, and the method combined the advantages of ISODATA method and maximum likelihood method. Finally the error source of automatic classification and scope of application were analyzed, and some approaches of improving accuracy of classification were discussed.

Keywords: percent ground cover, image analyses, features extraction, automation classification

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1. INTRODUCTION

Percent ground cover of vegetation is an important parameter which both agronomists and ecologists concern about. Not only does it reflect plant's dynamic growth in a long time, but also it is associated with abstraction of photosynthesis available radiation (APAR) of plant. It can reflect photosynthesis and transpiration (J E Adans et al., 1977). With the development of precision agriculture, remote sensing has provided an important tool for retrieving crop's water or fertilizer stress, monitoring crop conditions and offering decision information for the optimized agricultural production management. Percent ground cover of vegetation is closely related to remote sensing spectrum index. Stanhill (1972) pointed out that the differences of spectrum abstraction were due to the amounts of biomass and percent ground cover of vegetation (Stanhill G et al., 1972). Wanjura and Hatfield (1987) considered that the remote sensing crop index was affected by percent ground cover of vegetation more than by dry, fresh biomass or other parameters such as LAI (Wanjura D F et al., 1987). So, estimating percent ground cover of crop is of great importance in agriculture cultivation.

The traditional ways (J E Adans et al., 1977; Armbrust D V; Robert P, 1999) to estimate percent ground cover of crop are as follows: ①Agronomists estimate percent ground cover of vegetation by their experience in field. The main default of the method is the results are too subjective, and different persons may have different judging and values, even greatly. ②A ruler or electronic device can be used to estimate the values based on the theory of light capture around noon. The main default of the method is that it is affected by the weather and the direction when measuring, and it is a labor-consuming method. ③Percent ground cover of vegetation can be estimated by observing the pictures taken vertically and by counting the green elements in the photos.

So the ideal method to estimate percent ground cover of vegetation mainly includes following procedures: ①Cheap and easily manipulated equipment should be adopted. ②The in-situ data should be accurately and objectively treated. ③The method should save time mostly and be restricted the least when measuring in field. ④The process should be scarcely disrupted by the operator (Q Zhou, 2001).

The method to take pictures of crop canopy by digital camera, divide the image to crop and non-crop (soil and residuals) two classes, and calculate percent ground cover of vegetation in two-value image arithmetic could be a good choice among other methods. Along with the expanding market of digital camera, it is widely used because of the stronger space resolution,

larger storage capacity and cheaper price. Percent ground cover of wheat has been estimated through alternatively changing contrast and color balance of digital images by Lukina (Lukina E V et al., 2001) using software “Micrografx picture publisher”. Percent ground cover of corn has been estimated through alternatively changing the threshold of red, green, blue color, the hue, lightness, saturation or principle component analysis of red, green and blue color by Ewing (Robert P, 1999) using the software “RGBcal DyEye and RootEdge”. Percent ground cover of pasture has been estimated through alternatively changing the threshold of tone and saturation by Richardson using software “SigamaScan pro”. These research results demonstrate that percent ground cover of crop can be estimated by digital image analysis technology. However the estimation accuracy is affected by sunlight condition, the values are more precise in darkness than in sunlight. Moreover, these methods are labor-and-time consuming with strong subjectivity and frequent interpretation of the operators, so they are not satisfying now.

Winter wheat was chosen as materials in the research. With digital camera to take pictures, the research had adopted relevant analysis technology and put forward an automated extraction method to estimate percent ground cover of crop with more accuracy and objectivity. The aim is to offer a credible and rapid method to estimate percent ground cover of crop.

2. EXPERIMENTAL DESIGN AND METHODOLOGY

2.1 Experimental design

When measuring agricultural parameters, the digital image of winter wheat was taken at the Country Precision Agriculture Demonstration Base in the growing season in 2002. The experiment site is located in Changping district (40°10'6" to 40°11'2"N, 116°26'3" to 116°27'0"E). The varieties adopted in the experiment were horizontal “Zhongyou 9507”, erect “Jingdong 8” and moderate “Jin 9428”.

The factors included in the experiment compromised 4 fertilizer applications and 4 water strategies in order to study stress variability. There were 48 plots with 32.4m×30m for each. Four treatments received the following amounts of N at: 0,150, 300 and 450Kg/hm². Four water strategies were applied at rates of 0, 225, 450 and 675 m³/hm².

2.2 Field data acquisitions

2.2.1 Digital pictures acquisitions

The winter wheat in the 48 plots was taken pictures of by Sony camera, four times before full crop and twice after that. The first four days were Mar.25th, Apr. 2nd, Apr. 10th and Apr. 18 respectively, leaving the other two days in May. When taking pictures, the digital camera should be positioned erectly 1.5m above the ground between 11 o'clock am 12 o'clock. Because of the weather, some pictures were taken under the shadow of cloud. The pixel size of the photos is 2228×1712, which were stored in the computer in the form of JPEG (joint photographic experts group) and the total number of the image was 192.

As image of the digital camera was derived from the theory of center projection, which contributed to the distorted image when the field view angle grows larger, the image fringe has the most distortion. So only the 1284×1284 pixels in the center of the photos were taken to analyze and compute the percent ground cover of wheat.

2.2.2 LAI index measurements

After the digital pictures were taken of the winter wheat, the corresponding wheat should be collected thereafter. The dry biomass method was adopted to measure LAI in Laboratory. 50 to 100 standard leaves were chosen from each sample to measure leaf area (marked S1) and weigh the dry weight of these leaves (W1) and the rest leaves for each sample (W2). And the LAI of each sample can be calculated by the following equation: $LAI = S1 \times (W1 + W2) / W1$. The measured values of LAI were revised by CI-203 Laser Area Meter finally.

2.3 Methodology

2.3.1 Background-red, green, blue (RGB) and hue, lightness, saturation (HLS) color space

Digital camera has coupling filters of three different colors, each of the filter corresponds to a special sensitive spectrum band. The three different sensitive band are red(R), green (G) and blue (B) in Descartes color space.

Any color in the nature can be represented a point in the space, ranging from 0 to 255.

Another color space is Munsell system, which depicts color with hue (H), saturation (S) and lightness (L) in accordance to our vision. The space is defined as a two cone body with two vertexes, one is white and the other is black. Hue can be represented by ways of surrounding the vertical axis which itself represents lightness, and the emanative radius along the horizontal direction toward outside represents saturation (Robert P, 1999; Kenneth R, 1996; MEI An-xin, 2001). The colors depicted in either space can be transferred into the other.

2.3.2 Wheat image features

From re-green stage (Mar. 25th) to late jointing stage (Apr. 18th), it is a fast-growing period for wheat and the percent ground cover increases rapidly.

Before the cover reaches 100%, the height of wheat is low and leaves are all green without wilted ones. The hot-spot effect isn't apparent in sunlight. On the other hand, there are lots of bare land and crop residues. In digital image, the soil background and crop residues change greatly and the lightness of certain parts is higher than wheat. From the statistic values of RGB, variances of the two classes of objects are small. After the cover reaches 100%, winter wheat grows high and vertical layer has been shaped. On different layers of wheat leaves, the sunlight conditions vary. Under strong sunlight, the upper layers have strong hot-spot but the lower layers are in the shadow of upper layers. Bare land can hardly be seen in this period. Based on the theory that variances among different objects should be the least, the image can be classified as five classes as follows: ① wheat under sunlight without hot-spot; ②wheat under sunlight with hot-spot; ③wheat in the shadow; ④soil under the sunlight; ⑤soil in the shadow. There is wax on the surface of some wheat. Though only wheat and background need to be considered, however they can't be simply classified as two classes according to a certain program because there are lots of transitions between the two classes in changing sunlight.

2.3.3 Classification theory

The green vegetables appear green because of the strong abstraction in the red and blue spectrum band region and reflection of most of solar radiation in the green spectrum region. So the reflected radiation in the green spectrum is more than that in red and blue spectrum region.

As to the image before full crop, wheat satisfies the form $G > R$ and $G > B$. However, background (soil, crop residues, etc) covers a large portion in the image, and some crop residues appear brown or grey brown which also satisfy the form $G > R$ and $G > B$. The residues characters are that the RGB values have slight differences and the G value is the highest among the values. So it is necessary to eliminate residue pixels. It is a good way to distinguish green and brown objects with saturation when the RGB color space is transferred into HLS color space. In the HLS color space, saturation 60 degrees is kelly and 240 degrees is bottle green. The saturation value of crop residues is 0-20 degrees and 340-360 degrees, and that of wheat is 60-240 degrees.

As far as the image after full crop, wheat cover is above 80%, mainly around 90%. So wheat in the period can be classified as three sub-classes. (1) Wheat with hot-spot, it is strongly shined in the daytime and many lightness values are high even above 0.9. Part of soil under sunlight is relatively lighter, but the lightness value is less than that of wheat with hot-spot as the soil is lower than wheat. As a result, the threshold of L values is $x < L < 1$, in which x stands for the highest value of soil or a value above the highest one, in the paper it is set at 0.9. (2) Wheat under sunlight, the color of it turns from olivien to bright green, and the corresponding saturation values range from 90 to 240 degrees. It can't be misclassified as soil. (3)wheat in the shadow, the color of it is green and it satisfies the form $R > G$ and $R > B$. In order to avoid the effects of soil, $60 < H < 90$ is added as the limitation factor. Maybe there are overlapped parts between the first and the second part, but the soil has been separated successfully. Finally the wheat image can be got by combining the three subclasses: (1), (2) and (3) together.

2.3.4 Automated extraction algorithm on percent cover of wheat

According the automated extraction theory, the arithmetic is as follows:

(1)automated extraction arithmetic image before full crop

If the pixels satisfy the following form : $\{ R > G \text{ and } R > B, 60 \leq H \leq 240 \}$, they can be classified as wheat, or else as soil (R, G, B represents red , green, blue value respectively, and H represents saturation of pixel).

(2)automated extraction algorithm image after full crop

A. Transfer RGB color space into HLS color space, H ranges from 0 to 360 (0 represents red , 120 represents green, 240 represents blue), L and S range from 0 to 1 (2002).

B. If the pixels satisfy the form $90 \leq H \leq 240$, they can be viewed as wheat and belong to class one as mentioned above correspondingly. The color turns from olivine to bright blue and covers the corresponding part.

C. As to the pixels left, if they satisfy the form $x \leq L \leq 1$, they can be viewed as wheat and belong to class 2 mentioned above correspondingly (x is the highest value of soil or the value over the highest one, and it is usually set at 0.9).

D. For the rest pixels that are excluded from the above two classes, if the pixels satisfy the form: R

$R > G$ and $R > B$, $60 \leq H \leq 90$, they can be viewed as wheat and belong to class 3 as mentioned above.

2.3.5 Automated extraction program on percent cover of wheat

Based on the algorithm mentioned above, automated extraction program on percent cover of wheat is developed in IDL Language (MEI An-xin, 2001), which compromises three steps as follows. The first step is to read all the digital images and files in the same directory by calling READ_JPEG in the batch processing. The second step is to transfer RGB values to HLS values by calling COLOR_CONVERT. Using the extraction algorithm of wheat, digital image before and after full crop can be differentiated pixel by pixel and classification results (value one represents wheat and value zero represents background) are stored into array. The third step is to call IMAGE_STATISTICS to statistically classify the frequencies of one and zero in the array. Then figure out percent cover of wheat and export the value into files.

The program uses figure-user interface which can be easily manipulated, and the main procedures include: (1) put the image that needs to be treated with in the same directory; (2) run the program and input directory name; (3) the program will be automatically searching for all the images in the directory and classifies them individually; (4) export the results, each image will engendering a chart that contains classification results information and the percent cover of wheat data in all the images will be exported into a file.

3. EXPERIMENT RESULTS AND EVALUATION

3.1 Automated extraction accuracy on percent cover of wheat

Computer digital image classification includes supervised classification and unsupervised classification. Supervised classification firstly needs to choose training sample from manual work and the accuracy is closely

correlated with the amounts and the degree of representation of the samples chosen. The unsupervised classification needn't choose training sample because it combines and classifies the pixels by their similarity, so it is an automated method.

The most popular methods in the research are unsupervised classification—ISODATA method, supervised classification-maximum likelihood method (ML), and the automated extraction method suggested in the paper. And six images were randomly chosen in the experiment to classify wheat and extract the percent cover of wheat, the accuracy of the three methods were evaluated by the observing the digital pictures visually. Among the pictures, the former four were taken of before full crop and the two latter pictures are after full crop, which are shown in [Figure 1](#).

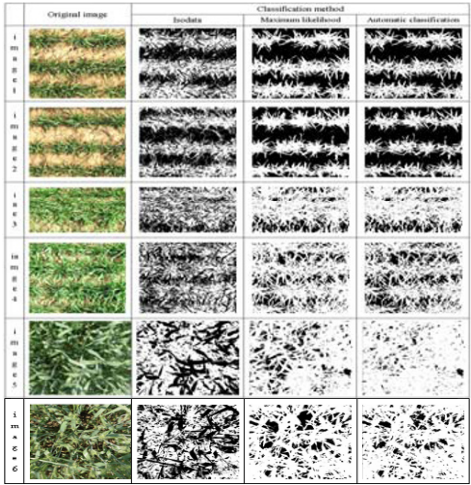


Fig. 1: Six cases of three classification results and their comparisons

ISODATA method and maximum likelihood method were run with software packet ENVI3.5 (2002). Before applying the maximum likelihood method in the whole image, the evenly distributed training samples of wheat and soil background should be chosen manually and respectively.

The classification results of the six images applying the three classifications mentioned above are shown in [Figure 1](#).

One hundred pixels randomly chosen in the six images were judged visually and classified as wheat and soil then compared the results of the three methods with the visual judgment. Rusesll’s error matrix (Russell G Congalton, 1991) provides reference to assess the accuracy of the three methods in the paper. The error matrix for accuracy assessment as [Table 1](#).

Table 1 The error matrix for classification accuracy assessment

Classification data	Reference data (from eye judgment)		
	wheat	soil	total
wheat	a	b	number of wheat
soil	c	d	number of soil

Note: a: the number of wheat pixels that have been classified as wheat in the reference data; b: the number of wheat pixels that have been classified as oil in the reference data; c: the number of soil pixels that have been classified as wheat in the reference data; d: the number of soil pixels that have been classified as soil in the reference data. The overall classification accuracy can be calculated by the form: $(a + d) / (a + b + c + d) \times 100\%$.

The classification accuracy of the six images with three different methods is shown in Table 2, respectively.

Table 2. Overall accuracy(%) of six image with three classification methods

	Isodata	the maximum likelihood	the automated extraction method
image 1	63	90	87
image 2	55	91	95
image 3	54	89	88
image 4	48	91	85
image 5	68	85	93
image 6	45	92	93
average	55.5	89.7	90.2

Table 2 indicates that ISODATA method has the lowest classification accuracy (45%-68%, 55.5% on average), and the maximum likelihood method and the automated extraction method both have high accuracy with little difference.

The comparisons of the three methods are shown in Table 3. The theories of them are different. In terms of choosing training samples, objectivity, batch processing, work amounts, processing time and individual participation of the three classifications, automated extraction method and ISODATA method are very similar, simple and fast. However the maximum likelihood method is labor-and-time consuming. With respect to classification accuracy, the maximum likelihood method and automated extraction method have higher classification accuracy than ISODATA method. So the automated extraction method based on the digital image features combines the advantage of ISODATA method and maximum likelihood method, it can provide the estimation rapidly with the least work amounts and high accuracy.

Table 3. The compare of advantage and disadvantage with three classification methods

	ISODATA method	maximum likelihood method	automated extraction method
theory	the overall statistic based on a whole image RGB, the iterative unsupervised classification by its average value and dispersion	the RGB statistic based on the training sample, classify the parts out of training samples in the image according to maximum likelihood principle	classification based on the characters of wheat and soil, their features in the RGB and HLS color space, and the sunshine effect on imaging
Choosing training sample	unnecessary	absolutely necessary, every image has its corresponding training sample	unnecessary
objectivity	strong objectivity	strong subjectivity, correlated with training sample	strong objectivity
Batch processing	enable	unable	enable
Work amounts	small	heavy	small
Processing time	short	long	short
Individual participation	occasionally	Frequently	occasionally
accuracy	very low	high	high
General evaluation	bad	fine	fine

3.2 Evaluation of the error and applicability of the automated extraction method

As to the digital photos, a small part of wheat may be easily misclassified as soil because of the strong similarity between soil and wheat in color and brightness, especially most of the pictures were taken in sunlight. In addition, the transition from wheat to background can easily be confused due to the mixed pixels in a digital picture.

Were there absolutely not hot-spot effect on wheat leaves (under obscure sunlight or cloudy whether), the classification accuracy would increase somewhat.

As to the digital picture after full crop, the bottom wheat was covered by the top wheat and received less sunshine. Probably some of the leaves can be misclassified as soil background due to the dark environment.

The accuracy of the latter two images after full crop was higher than that of the former four images before the full crop. Soil received less sunshine after full crop and it can be distinguished from wheat easily because they were very different from each other by the color and lightness.

The soil type in the research was alluvial soil. With different soil moisture and under different sunlight the soil appeared grey, French grey, filemot, buff and khaki in the digital image. The research results can be applied to wheat grown on soil types of black, grey, khaki etc. series. Further

discussion and validation of the applicability of the red or other soil types were still necessary.

By adjusting some parameters, the automated extraction method can be applied to extract percent cover of soybean, clover, cotton, corn and rice and to monitor crop dynamic growth.

3.3 Estimation of leaf area through percent cover of wheat

When regressed against percent cover of wheat before full crop extracted by using digital image and the measured LAI, it is found that the two showed exponential relationship, which reached highly significant level, and the multiple correlation coefficient was 0.743. It is consistent with Toby's research result (Toby N, 1997).

4. DISCUSSION

This paper brings forward the automated extraction method of wheat percent cover using digital image analysis technology to process the pictures taken with digital camera. The method eliminates operator's subjectivity and it has high classification accuracy and satisfying results. In addition, as the estimation accuracy is affected less by the sunshine conditions, the satisfying results retain whether in sunshine or in shadow.

Furthermore, the LAI before full crop could be estimated by percent cover of wheat from the digital image.

As to the wheat image before full crop, part of it may be misclassified as soil due to strong sunshine and hot-spot phenomenon. Part of the pixels of the transition between wheat and background may be misclassified because of mixed pixels. The bottom leaves received less sunshine as the top leaves, may be misclassified after full crop.

The new algorithm in the paper is based on single pixel in wheat digital image without considering its relationship with surrounding pixels and prior knowledge, such as that wheat was planted along rows, wheat is composed of many pixels while the isolated pixel indefinitely isn't wheat, and provided there was hallow hole on the physical surface of wheat leaves (generally the hot-spot part), the hallow hole would be wheat. In conclusion, in order to improve estimation accuracy, physical morphologic algorithm should be combined with and prior knowledge should be added for further research.

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RESEARCH ON THE METHOD OF GIS-BASED ANALYSIS ON AGRICULTURAL REGIONAL COMPETITIVE INDUSTRIES

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Abstract: The author introduces the main content of the research on the GIS-based regional agricultural analysis system of competitive industries, including the significance, the main contents and the implementation methods of the research, focusing on the classification of agricultural economic indicators for regional competitive industries, on the realization of regional choice based on GIS, and on the design of a computer system. The advantages of the regional agricultural industry from the analysis conduct a number of meaningful explorations on the ways and means, particularly making a number of new attempts on the use of GIS to analyze the agricultural regional competitive industries.

Keywords: GIS, Agricultural regional planning, System

1. INTRODUCTION

1.1 Regional management of agriculture is necessary for the development of modern agriculture.

Agricultural modernization includes the modernization of technology and management. Since China has a vast territory, there are many differences in climate, natural resources, endowments, and the people's living habits and agricultural development, which require a regulatory control measure to

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achieve inter-regional complementary and the relative balance of resources. So each area can form their own characteristics of the regional agricultural economy and prevent over-blind competition, which may lead to the waste of resources, caused by a sudden swing into action, without careful preparation, and the duplication of inter-regional input during the structural adjustment. Regional management can make the agricultural production of entire region become an organized workroom-style production workshop to provide high-quality, high efficiency and high-yield agricultural products.

1.2 The concept of agricultural regional management

Agricultural regional management includes social, economic, technical management. In social management, establishing a collaborative organization adjusting to social development trend is necessary. In the economic structure and development, following the restrictions of the natural conditions, the management is supposed to be market-oriented, to strengthen regional intergovernmental organization and interaction, to make the regional structures be complemented to each other according to local conditions, thus to establish a series of secondary and tertiary industries, to stimulate the growth of regional economy, and to optimize resource allocation and portfolio. In technology, we should establish a technology management system that adjusts the mechanisms for market transformation, reduce the cycle time of transforming agricultural technology into productivity, and improve the motivation and ability of technological innovation. Agricultural regional management is the general idea of agricultural development. The development of agriculture should be based on the perspective of the overall situation and pay attention to forward-looking, regional, and actively implement the adjustment of industrial structure, raise the level of agricultural operations. The implementation of unified guidance and management can make the quality of agricultural products achieve a uniform standard, effectively control the quality of agricultural products amounted to less than the state safety standards caused by technical problems, and can also promote the development of market and withstand market risks together.

1.3 Issues to be solved in our research

According to the regional spatial distribution of major agricultural industry, agricultural resources and economic data, we can establish county-based regional advantages industry evaluation indicators, in which the characteristics of region's main agricultural industry are supposed to match the environmental parameters of natural resources; study the advantage index and the methods of evaluating the comprehensive competitiveness of

regional competitive industries; design and develop a regional agricultural analysis system of competitive industries based on the evaluation indicators and evaluation methods. According to the basic data, the system can analyze and evaluate the regional advantages and characteristics, to provide a scientific basis for the determination of regional competitive industries and the rational adjustment of industrial structure in the region, thus achieving the implementation of agricultural regional management.

2. RESEARCH METHODS

2.1 Design evaluation indicators

According to conventional agricultural regional evaluation methods, evaluation indicators usually include the following aspects:

2.1.1 Natural resources

Natural resources impacting on regional agricultural production mainly include the following three aspects: land resources, climate and water resources.

A. Land resources

Being the sites for human's life and production, land resources are the most basic means of production for agricultural production and planting industry. In planting production, land resources not only affect the status of crop production, but also restrict the production structure of planting industry. The characteristics of them include quantity limitation, fixed location and quality differences. The total land resources are limited and subject to the constraints of nature. They occupy a fixed position after forming, which needs a very long time and corresponding conditions, so that people can not move them in space.

In our system, the indicators referring to land resources are followings: area of arable land, area of harvest guaranteed whether drought or floods, and so on.

B. Climate resources

Climate resources are the comprehensive long-term performance of all kinds of weather elements, including light, heat, water, wind and atmospheric composition. They are the main natural resources which are indispensable to planting production. Under certain technical and economic conditions, they can provide material and energy for human beings. They are

the key factors that constrain and affect agricultural production and its distribution. The characteristics of them include the heterogeneity of the region, the difference in time and the renewability.

C. Water resources

Water resources are the most active environmental factors. Natural reserves of water are diverse, and they generally refer to the surface water and groundwater formed by precipitation. They have a great impact on the production of various regions' planting industry, and supposed to be an important condition for the growth of crops. The characteristics of them include the regional scarcity of quality and quantity, functional irreplaceability and renewability.

In our system, the indicators referring to water resources are followings: irrigated area, and so on.

2.1.2 Social resources

A. Labor resources

Labor resources refer to the sum of the ability to work within the scope of an overall population, also called human resources. Labor is the fundamental element of the national economy, constituting the basic prerequisite for socio-economic operation, promoting the development of material resources, and actively adapting to material resources. It is a major production factor in crop production, the richness of its resources directly affects the situation of crop production comparative advantage.

Its characteristics include subjective initiative, the restriction of time, the difference in quality, creativity and renewability.

In the system, the indicators referring to labor resources are followings: rural labor, staff number, and so on.

B. Funds

Funds refer to the value contented in the process of production and circulation process, keeping constant moving and being value-added. Being a means, funds are used by workers to increase the social wealth and social value. They are supposed to be a tool to carry out the socialist economic construction and constantly improve people's living standard. The number of capital input to agricultural production directly affects the level of production efficiency. The characteristics include homogeneity, mobility and value-added.

In the system, the indicators referring to funds are followings: total income, agricultural income, industrial revenue, livestock income, service income, planting income, forestry income, fisheries earnings and so on.

C. Technology

The development of production is closely linked to scientific and technological development. Being the primary means to improve labor

productivity, science and technology is an important factor of promoting regional economic development. The improvement of agricultural production technology can greatly improve the efficiency of agricultural production; increase the level of crop production advantages and their income. Its technical features include that it can be commercialized, developed, dedicated, and promoted sharing.

In the system, the indicators referring to technology are followings: per-mu yield of all kinds of food crops, per-mu yield of cash crops, and so on.

2.1.3 The classification of indicators in the system

Based on the above indicators, we will divide the indicators of the system into followings according the analysis and the needs of evaluation:

- A. resource data: including land, water, staff and so on;
- B. production of food crops: mainly including gross food yield and per-mu yield of the main food crops (such as wheat, corn, rice, etc.);
- C. production of economic crops: per-mu yield of major economic crops (such as cotton, oil-bearing crops, hemp, sugar, etc.);
- D. aquaculture industry: including aquaculture industry of fishes and poultry livestock;
- E. township enterprises: the number of township enterprises, the number of the staff, the number of total income, profits and taxes, and so on;
- F. major economic indicators: total income, the ratio of agricultural income, the ratio of industrial income, the ratio of livestock income, the ratio of planting income to the agricultural income, the ratio of forestry to the agricultural income.

2.2 GIS spatial database related to agricultural economy database

Based on the GIS development tools named SuperMap, using the county digital map and its spatial database, using the county code for the key, the spatial database is linked to the agricultural economy database. Although increased the workload of the design process, this approach has the following advantages:

- a. The properties of the original spatial database are not changed and the import volume of the agricultural economic data is reduced;
- b. The integrity of the agricultural economy database can be ensured, and it will provide the future security of data with convenience.

2.3 Calculation of regional evaluation indicators

2.3.1 Identify the region and neighboring ones based on GIS technology

During the analysis, determine the region and the neighboring comparative ones is supposed to be the first step. The region to be analyzed takes county as a unit, and the region used as the contrast can be the neighboring ones.

A. Regional choice

There are two ways to choose the region:

a. Choose the region according to its name

According to the name of the county to be analyzed, select the province which the county belongs to at first, and then the county. After the name of the county been chosen and determined, the identified region will be highlight on the county map by the system according the chosen name. The following is the process: Select province name -> Select county name -> Enter the spatial database and search the county name -> Highlight the search results on the map -> Get agricultural economic data of the corresponding region.

b. Choose the region on the map directly

According to the map of the county displayed in the system, click on the map to choose the region directly, and the region will be highlighted.

B. The choice of the (neighboring) region used as the contrast

The selection of adjacent area is based on GIS spatial analysis functions, choosing the neighboring regions of the selected area as the region's contrast, and getting agricultural economic data of these regions from the corresponding database, to prepare for calculation.

2.3.2 Calculation using comparative advantages of regional agricultural industry

According to the indicator system, the comparative advantage calculation is based on several aspects, such as the resource data, the production of food crops, cash crops production, aquaculture, township enterprises and major economic indicators, and so on. Calculated as follows:

A. Calculate the ranking of the indicators

According to the overall number of the selected regions and comparative regions, and the design of the indicator system under the project, calculate the regional rankings of various economic indicators, including the 5 indicators of agricultural resources; the 8 calculation indicators of food crops production, such as the per-mu yield of various types of food crops and so on;

the 7 calculation indicators of economic crop production; the 4 indicators of planting industry, the 5 indicators of township enterprises; and the 9 major economic indicators.

Based on the results of the above calculation, the strengths and weaknesses of the production and economic indicators in the selected regions and comparative ones can be found, and thus largely determine the region's situation of agricultural competitive industries.

B. Calculating the overall situation of the evaluation

Based on the above six categories of indicators, according to the rating of "A, B, C, D, E", calculate the overall level of selected regions in terms of regional comparison. The followings are the process of calculation: the numerical sum of regional rankings divided by the number of regions, and the results then divided by 5. The smallest number will be ranked as "A", etc. From the orders, one can see category ranks of the selected areas and comparative regions, then the overall situation of the selected area compared to the comparative regions.

2.3.3 The expression of the results of the overall evaluation and calculation

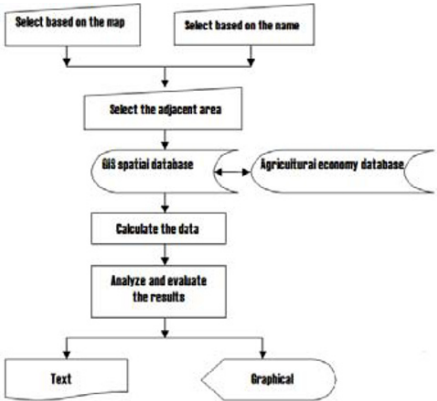
A. Graphical expression

The results of calculation can be shown in the form of histograms, according to the classification of the indicators. So users can directly see the situation of the indicators of the selected regions and comparative regions.

B. Text expression

The results of the calculated rankings of the indicators and the overall evaluation results of category indicators will be described and displayed in the form of text.

The primary process of the system is shown in Figure 1:



3. FUNCTIONAL DIVISION OF THE SYSTEM

3.1 Data management module

It is composed of GIS spatial database management and agricultural economy database management, including data importing, data editing, data maintenance, and so on.

3.2 Statistical calculation module

According to the requirements of functional design, complete the basic data extraction and simple calculation, for example, calculated per-mu yield based on the sown area of wheat and its gross yield; according to the data of the selected regions and comparative regions and the results of calculation, sort the results, and so on.

3.3 Analysis and evaluation module

According to the results and their sort, in accordance with the classification of agricultural economic data, provide the comprehensive evaluation of the region in the agricultural industries and economic indicators.

3.4 Input and output module

It includes the interaction of user-related part, such as: map, the choice of regional data, the graphics of calculated, analyzed and evaluated results, the screen display of text expression and print output, and so on.

4. CONCLUDING REMARKS

As the great differences in natural resources, social resources, economic infrastructure, technical conditions and other aspects between regions, the comparative advantages of our country's crop production have a big difference. First of all, the comprehensive comparative advantages of the crop production in different regions have differences. Some areas have crops with comprehensive comparative advantage, which may be in a relatively disadvantageous position in other regions. The crops with a relatively disadvantageous position in some areas of crops may have relatively comprehensive advantages in other regions. Secondly, the overall production

in agriculture has different strengths. In some areas, planting industry as a whole may have strong comparative advantages and in some other areas, planting industry may be weak as a whole. In the process of the crop structure adjustment, not only give full play to the comprehensive comparative advantages of all kinds of crops in the region, we should also take full advantage of the planting industry as a whole in comparative advantages, not only expand the crop production with comprehensive comparative advantages, and reduce the one with comparing disadvantages, but also take full consideration for the comparative advantages of planting industry at the same time, then planting industry will be done to improve efficiency, and the income of farmers will be increased.

The analysis on agricultural regional competitive industries proposed in the paper, has integrated the natural, social, economic and many other factors, made certain sense to the regional crop structure adjustment. However, the regional industrial structure adjustment is a complicated systematic project. The results of this study can not simply be a relatively perfect solution to the problem. We are also trying to conduct much deeper study ranged from the contents of indicators to the methods of analysis, there are many issues worthy of further exploration and study.

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STUDY AND APPLICATION ON CLOUD COVERED RATE FOR AGROCLIMATICAL DISTRIBUTION USING IN GUANGXI BASED ON MODIS DATA

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Abstract: Based on analyzing of the physical characteristics of cloud and importance of cloud in agricultural production and national economy, cloud is a very important climatic resources such as temperature, precipitation and solar radiation. Cloud plays a very important role in agricultural climate division. This paper analyzes methods of cloud detection based on MODIS data in China and Abroad. The results suggest that Qianjun He method is suitable to detect cloud in Guangxi. State chart of cloud cover in Guangxi is imaged by using Qianjun He method. We find out the approach of calculating cloud covered rate by using the frequency spectrum analysis. At last, the Guangxi is obtained. Taking Rongxian County Guangxi as an example, this article analyze the preliminary application of cloud covered rate in distribution of Rong Shaddock pomelo. Analysis results indicate that cloud covered rate is closely related to quality of Rong Shaddock pomelo.

Keywords: MODIS, cloud covered rate, Rong Shaddock pomelo, distribution

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1. INTRODUCTION

A cloud is a visible aggregate of tiny water droplets and/or ice crystals suspended in the atmosphere and can exist in a variety of shapes and sizes. Some clouds are accompanied by precipitation; rain, snow, hail, sleet, even freezing rain. Clouds are the maternal body of natural precipitation and precipitation enhancement, the main natural factors influencing moisture supply and water regulation of upland crops, the main regulator of the underlying surface solar radiation . Clouds have specially significant effect on the energy balance of the earth atmosphere. The radiative forcings by cloud is recognized as the one important contributors for climate change. Clouds are closely related with people's daily lives and manufacture .In agricultural production, different cloud layer and cloud cover time have also affected different in different season or different period of time . In a critical time of spring sowing , moisture in the fields was evaporated in warm and fine weather , spring drought may cause and have an bad effect; Clouds could effectively screen out much of the sun's radiation in the summer, it can prevent the seedling of crops and fruits of Shatian pomelo, oranges ,etc. from injury of the sun's radiation. In winter, two reasons may cause freeze injury .one is longer cloud cover time in the daytime, the other is longer clear time at night. Land have not enough solar radiation to absorb energy because of cloud cover in day; freeze injury hurt crops especially warm-temperate crops.

Clouds are vital significance to the national economy .It is not only in plant diseases and insect pests of agricultural production but also in safety of civil aviation or on water or air. Ground proximity clouds may generate Fogs under some situations. Fogs have become the first largest killer on highway. An airplane can't take off on schedule because of the heavy fog.

Clouds are determined by main physical factor of climate formation. Cloud cover changes the balance of underlying surface earth-atmosphere radiation, leading to the surface energy and moisture budgets of earth-atmosphere system. To some extent, cloud is a very important climatic resources such as temperature, precipitation and solar radiation. It is helpful to understand characteristics of cloud .

A completely clear day might seem boring in a cloud observer project, but in fact this is one of the most important things a surface observer can report. Clear sky is easy to detect from the ground, because one observes against the uniform background of space. When looking down at the Earth, however, the background is highly variable and can make cloud detection very hard. In conventional meteorological observation, cloudiness estimation is using by visual observations of agro-meteorological observer. The method is :The sky

is divided into 10 equal divisions ,cloud covered divisions are regarded as cloudiness .

Clear (cloudiness<3/10)

Cloudy (cloudiness 3/10 to 8/10)

Overcast (cloudiness>9/10)

Using this method to estimate cloudiness, the result represents only observation station. Conventional meteorological observation can't accurately reflect the change of cloudiness of local area and beyond observation. With the development of satellite remote sensing technology, meteorological satellites and weather radar are using to monitor cloudiness . According to analysis theory and present Situation of cloud detection , this paper mainly studies on obtain cloud coverage rate image of Guangxi Province based on MODIS(Moderate Resolution Imaging Spectroradiometer) data . The objective is to make better use of cloud resources to serve the society.

2. CLOUD DETECTION METHODS

2.1 Basic principle and research status of cloud detection

Clouds are generally characterized by higher reflectance and lower temperature than the underlying earth surface. As such, simple visible and infrared window threshold approaches offer considerable skill in cloud detection. However, there are many surface conditions when this characterization of clouds is inappropriate, most notably over snow and ice. Additionally, some cloud types such as thin cirrus, low stratus at night, and small cumulus are difficult to detect because of insufficient contrast with the surface radiance. Cloud edges cause further difficulty since the instrument field of view will not always be completely cloudy or clear.

MODIS offers the opportunity for multispectral approaches to cloud detection so that many of these concerns can be mitigated; additionally, spatial and temporal uniformity tests offer confirmation of cloudy or clear-sky conditions.

There are many MODIS cloud algorithms :

Menzel et al., use infrared band to detect cloud(Menzel,1993), the six concrete judgment basis as follows: $TB11 + a(PW) \times DTB$ (11,12), $TB11 + b(PW) \times DTB$ (11,8,6), $TB11 + C(PW)$, DTB (4,11), $TB13$, p.138, where a, b, C is respectively function of PW . if one of six judgment basis more than

specific threshold shows that this pixel is covered by cloud, if none of six judgment basis more than specific threshold shows that this pixel is clear.

The algorithm offered by MODIS cloud mask team is widely used in the world at present. This algorithm is determined for good data only (i.e., fields of view where data in MODIS bands 1, 2, 4, 5, 6, 7, 17, 18, 19, 20, 22, 26, 27, 28, 29, 31,32, 33, and 35 have radiometric integrity). Incomplete or bad radiometric data creates holes in the cloud detection. Additionally, the cloud mask requires several ancillary data inputs such as sun angle, azimuthal angle, topography , ecosystems , Daily NISE snow/ice map and Daily sea ice. The algorithm is easily influenced by working condition of detector.

In China, an automatic cloud detection algorithm is applied based on the spatial texture analysis and neural network(Song, 2003) , judgment basis as follows: $\rho_{0.66}$, TB_{12} , $\rho_{0.87}/\rho_{0.66}$, $INDV = (\rho_{0.87} - \rho_{0.66}) / (\rho_{0.87} + \rho_{0.66})$, $DTB(3.7,11)$, $DTB(8.6,11)$, $ICD: (\rho_{0.66} - \rho_{0.936}) / (\rho_{0.66} + \rho_{0.936})$. Xia Sheng puts forward a new method to discriminate cloud from clear scene utilizing M ODIS visible and infrared bands data, which proved the efficiency of the method in mid or low latitude regions with vegetation or ocean background(Sheng,2004).Through analyzing meteoric characteristics of cloud in different spectra and integrating the spectral characteristics of MODIS,the authors(He,2006) put forward a new cloud detection method based on multi—spectrum synthesis.

2.2 Cloud detection method

Based on the characters of semi-tropical climate,topography,vegetation in Guangxi, the methods for cloud detection in MODIS data are analyzed and compared . The results suggest that the method offered by Quanjun He is suitable to detect cloud in Guangxi. The Human Computer Interaction Platform based on the slip threshold figure is used in our cloud detection method.

The MODIS bands used in the cloud detection method are identified in Table 1

Table 1. MODIS bands used in the MODIS cloud detection method

Band	Wavelength(μm)	Comment
CH1	0.620~0.670	clouds, shadow
CH6	1.628~1.652	snow, shadow
CH8	0.405~0.420	ocean
CH26	1.360~1.390	thin cirrus, high cloud
CH29	8.400~8.700	Brightness temperature difference
CH31	10.780~11.280	window threshold
CH31	10.780~11.280	window threshold

(concrete method can be seen Quanjun He et al., 2006)

3. OBTAIN CLOUD COVERAGE INDEX IMAGE OF GUANGXI PROVINCE

3.1 Study area and data source

The study area is located in Guangxi province, south of China. It's latitude is $20^{\circ}54' \sim 26^{\circ}23'N$ and longitude is $104^{\circ}29' \sim 112^{\circ}04'E$. Its total area is 236700.0 km^2 . It belongs to monsoon region of south subtropical zone and north tropical zone without four clearly demarcated seasons of spring, summer, autumn and winter. The climate here is hot and humid in summer and warm and dry in winter.

Data input to the cloud detection method is assumed to be calibrated and navigated level 1B radiance data which offered by National Satellite Meteorological Center and DVBS of GuangXi Institute of Meteorology. The time segment of complete data is from 2001 to 2006.

3.2 Cloud covered rate image in Guangxi

The detailed work and the corresponding results are as follows:

(1) Using Quanjun He method to detect cloud of all MODIS data, We assumption that:

$$R_{ij} = \begin{cases} 1, & \text{cloud pixel} \\ 0, & \text{no-cloud pixel} \end{cases} \quad (1)$$

Where: R_{ij} is pixel of MODIS image.

State chart of cloud cover is obtained based on cloud detection of R_{ij} .

(2) Calculating cloud covered rate by employing templates

Suppose size of image R is $m \times n$, we employ templates as follows:

$$\begin{aligned} P &= \{ R_{ij} \}_{m \times n} \quad i, j = 1, 2, \dots, p \\ Q_p &= \{ q_{f,g,p} \}_{m-p+1, n-p+1, \min(m,n)-1} \end{aligned} \quad (2)$$

Where: P is gliding template, Q_p is spectrum statistical Matrix

For all sample graph, use formula (2) to investigate region of cloud covered. If $i=1$ and $j=1$ in gliding template P , corresponding position of image R is f_1, g_1 , then corresponding point in Q_p is point f_1, g_1, p . According to formula (1), if $\{ R_{ij} \} = 1$, that is template covered by cloud, The count of Q_p add s one, otherwise, the count of Q_p keeps invariant.

Using above methods, we obtain cloud covered rate image of Guangxi by counting all MODIS data (Fig.1- Fig.5).

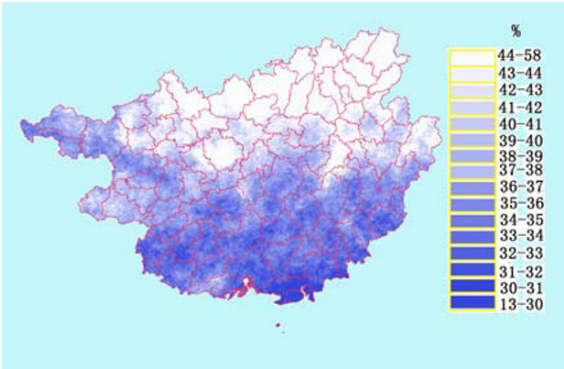


Fig.1: The annual-averaged cloud covered rate image of Guangxi

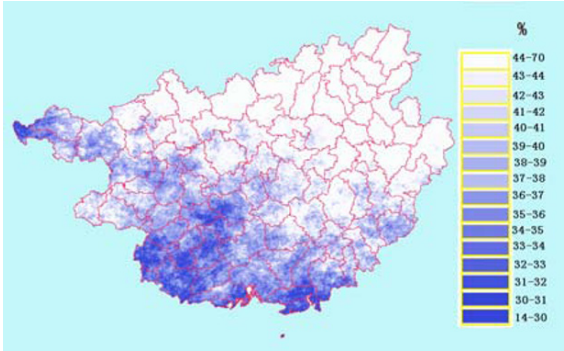


Fig.2: The spring- averaged cloud covered rate image of Guangxi

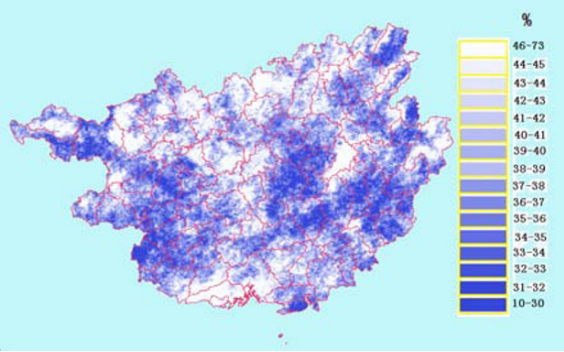


Fig.3: The summer- averaged cloud covered rate image of Guangxi

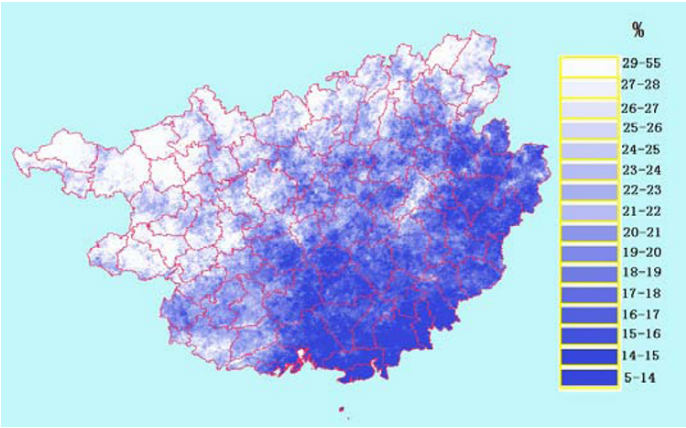


Fig.4: The autumn- averaged cloud covered rate image of Guangxi

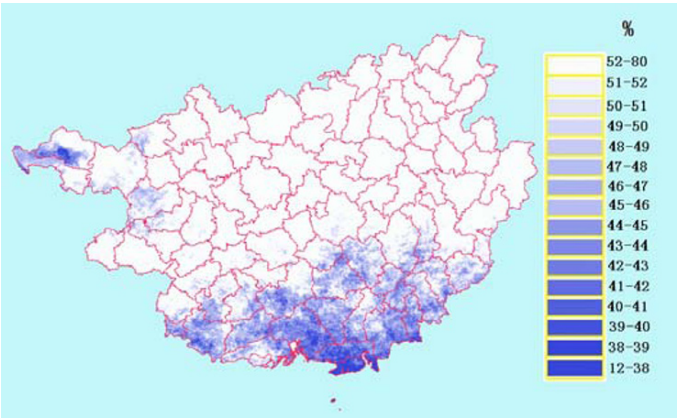


Fig.5: The winter- averaged cloud covered rate image of Guangxi

3.3 Preliminary application of cloud covered rate in distribution of Rong Shaddock pomelo

Shaddock pomelo is a treasure of Chinese pummel, and is primary export fruit,mainly distributed in some areas of Guangxi Province Guangdong Province Sichuan Province and Hunan Province. During the last decade, along with the rapid development of Shaddock pomelo production, many problems have appeared such as taste of fruit reduced, economic benefit drops and low unit yield. (Su,2005)According to the requirement of Shatian pomelo cultivar to climatic conditions,and based on the analysis of the climatic data of 90 weather stations accumulated in 30

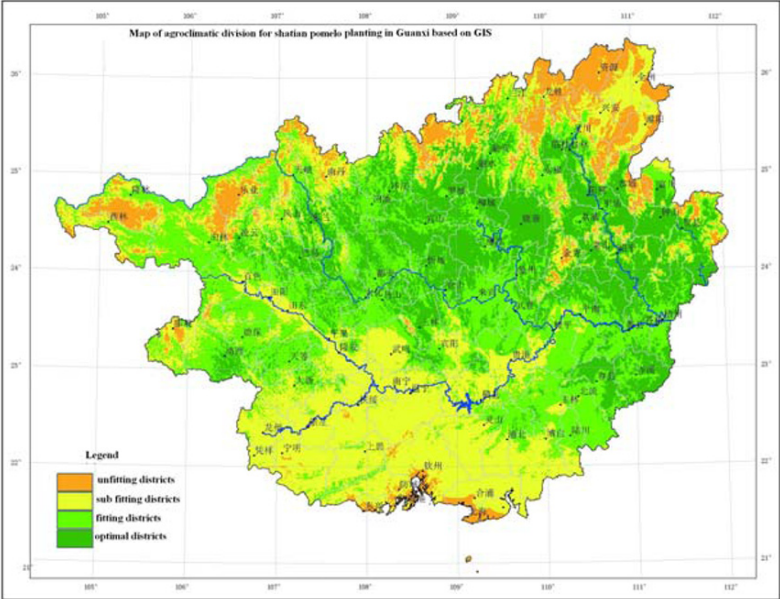


Fig.6: Map of agroclimatic division for shatian pomelo planting in Guanxi based on GIS

based on GIS years and the fundamental geographic data on the scale of 1 to 250 000 in Guangxi,the optimal,fitting,sub fitting and unfitting districts for growing Shatian pomelo cultivar are regionalized(Fig.6) .

Rongxian County is one of high quality producing areas in Guangxi, we take Rongxian County as an example to analyze the preliminary application of cloud covered rate in distribution of Rong Shaddock pomelo .

Fig.7 show that A is the optimal district in Rongxian County, B is the fitting district.In Fig.1 , cloud covered rate is relatively low in the central and northern regions of Rongxian County , A have comparatively high absorption for Solar Radiation, so the annual-averaged temperature is comparatively high .It is helpful to growth of Shaddock pomelo. B have comparatively low absorption for Solar Radiation, It is not benefit to growth of Shaddock pomelo.Shaddock pomelo starts flowering in April. Good weather is benefit to flowering . Cloud covered rate of A is lower than that of B (Fig.2),so A has ensured a good flowering rate . In the growing season, cloud covered rate of B is higher than that of A (Fig.3), high cloud covered rate may lead to abnormal weather. It is not helpful to fruit set percentage of Shaddock pomelo. The fruit maturation period is in the last ten days of October, enough light radiation is favorable to the sugar accumulation and flavor keeping in fruits(Fig.4) . Suitable light radiation is

benefit to Aromatic Mixture, so Shaddock pomelo has a strong aroma. But strongly light radiation may cause heat injury to fruit of Shaddock pomelo.

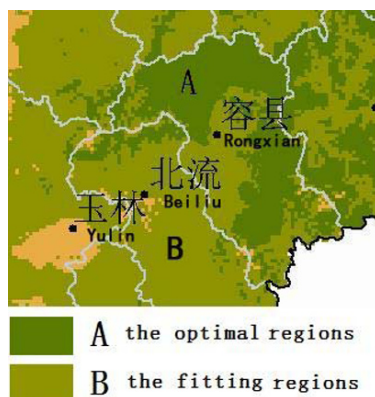


Fig.7: Map of shatian pomelo planting in Rongxian County Guanxi

4. CONCLUSION

(1)Cloud covered rate was first used for agricultural climate division in this paper . Analysis results indicate that cloud covered rate is closely related to quality of Rong Shaddock pomelo. Cloud is a very important climatic resources such as temperature, precipitation and solar radiation. It is helpful to agricultural climate division .

(2)Calculation method of cloud covered rate image is given in this paper.

(3)Period of MODIS data is relatively less ,it has certain effect to agricultural climate division .But it does not affect methods utility. With the development of satellite remote sensing technology, questions will be solved.

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RESEARCH ON THE SPATIAL VARIABILITY OF SOIL MOISTURE

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Abstract: China is a country seriously suffering from the lack of water resource, especially the north of China (a dense area) where there are more agricultural production than other places in China. Therefore, some have become most important problems which should be settled down right now for precision agriculture: saving the water of agriculture, optimizing the water for cropland as well as making use of soil moisture effectively. To realise the potential of soil-moisture, protect the water source, strengthen the management of the soil moisture of farm, design the irrigation and drainage, monitor the soil-moisture, etc., the data collection of soil moisture and the study on how to could provide the far-reaching and academic significance of guidance together with higher regional and practical use value. The IDW, Spline and Kriging in the Spatial Analyst of ArcGIS 9.0 are applied on drawing the distributing map of soil moisture and it also offers the theoretical foundation for the connection between studying soil moisture and enhancing the yield.

Key words: Precision agriculture, Geographic information system, Spatial variability, Spatial interpolation

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1. INTRODUCTION

Soil was inhomogeneous and continuous nature. Actual instance in the field indicated, in the synchronization, soil speciality also had obvious difference on the different spacial situation, this property was named the spatial variability of soil moisture (Hua et al., 1992). The most intuitionistic mode of the spatial variability of soil moisture was the spatial distribution map of soil water. Therefore, the all-important work and base of Precision Agriculture is producing the spatial distribution map of soil moisture reliably.

This study discussed the spatial variability of soil moisture , and applied Inverse Distance Weighted , Spline and Kriging interpolation of ArcGIS 9.0 to produce the spatial distribution map of soil moisture, it could offer the scientific evidence for farm management system.

2. BASIC THEORY AND METHOD OF THE SPATIAL VARIABILITY

2.1 Inverse Distance Weighted Interpolation

IDW (Inverse Distance Weighted) is a common and handy interpolation, it take an average with weight between interpolation points and modal points, its weight is more and more bigger with interpolation points.

On the assumption there are a series of discrete points, it is known the sum of coordinate points for $X_i, Y_i, Z_i (i = 1, 2, \dots, n)$.

$$Z = \left[\sum_{i=1}^n \frac{Z_i}{d_i^2} \right] / \left[\sum_{i=1}^n \frac{1}{d_i^2} \right]$$

In which: $d_i^2 = (X - X_i)^2 + (Y - Y_i)^2$

With the application of IDW, interpolating unit value is generated by averaging the values collected from all sampling points in nearby locations. IDW is a process which requires the evenly distribution of discrete points and their enough denseness to indicate local superficial changes in the analysis.

2.2 Spline Interpolation

There are two calculation methods to produce Spline function interpolation: Regularized Spline and Tension Spline. Regularized Spline produces a smooth and gradual surface and interpolation value could be

much higher than the spectra of the values collected in sampling points. Tension Spline produces a hard surface based on characteristics of the phenomena to be formed and its interpolation result are more fitted within the spectra of values collected in sampling points.

A general formula of Spline interpolation is:

$$Z_0 = \frac{\sum_{i=1}^s Z_i \frac{1}{d_i^K}}{\sum_{i=1}^s \frac{1}{d_i^K}}$$

In this formula, Z_0 is the estimated value of Point 0; Z_i is Z value of Control Point i ; d_i is the distance between Control Point i and Point 0; s is the number of Control Point in estimating; k is a designated power.

2.3 Kriging Interpolation

Kriging Interpolation is the most common interpolation method in geostatistics (Webster R. et al., 1985; Trangenin B. et al., 1985). It is the method of optimized and precise estimation of partial variables in unobserved locations with application of original data and configuration of semi-variance function (Wollenhaupt N. C. et al., 1997). It does not only consider the distance but also apply the variance function and configuration analysis to consider the relation between the spatial distribution of known sampling points and the spatial location of unknown sampling points. Kriging method produces the value for unknown sampling points with values for known points. This is shown:

$$Z(x_0) = \sum_{i=1}^n \lambda_i Z(x_i)$$

$Z(x_0)$ was the value of unknown points, $Z(x_i)$ was known swatch points around unknown points, λ_i was the power that point i to unknown points. For satisfying non-Biased and optimality, passed establishing Kriging formula to ascertain weight coefficient (Li et al., 2006) :

$$\begin{cases} \sum_{j=1}^n \lambda_j \gamma(x_i, x_j) + \mu = \gamma(x_i, X) \\ \sum_{i=1}^n \lambda_i = 1 \end{cases}$$

$\gamma(x_i, x_j)$ is covariance function in sampling points, $\gamma(x_i, X)$ was covariance function between sampling points and interpolation points, μ was Lagrange multiplier.

3. DESIGN OF THE EXPERIMENT

Experiment farmland was a soybean field of Heilongjiang Daxijiang farm, its area was about 9.8 hm². June 27, 2006, soil moisture was measured with the help of GPS and measuring instrument of soil moisture, grid was setting by 15m×15m, about 250 points, sampling deepness was 10cm. 9800 Uranus dual-frequency RTK of the South Mapping Co. was used to measure the evaluation data of this land.

Sampling mode of soil moisture was point sampling(Joseph K. Berry et al., 1999;Wollenhaupt N C et al., 1997; Hao et al., 2002), inerratic grid sampling disjoins the farmland to equal area grid. It is simple and exercisable, is the most effective one of sampling method and is much more precise than random sampling mode. Besides pane shape, triangle grid, rectangle or hexagon are able to be used. Inerratic grid sampling distribution is shown in figure. This research considered sampling convenience and actual condition, compartmentalized grid along ridge in a field generally.

This research on spatial variance of farmland moisture started with sampling soil. The instruments for sampling soil include GPS and measuring instrument of soil moisture. Mostly, the sampling deepness equals the tilth deepness. In this research, the sampling deepness is 10cm.

4. EVALUATION DATA ANALYSIS

Evaluation Map is produced with the use of 9800 Uranus dual-frequency RTK of the South Mapping Co. to measure the evaluation data of this land, the set-up of network 15m×15m, the application of Kriging Interpolation of Spatial Analyst model in geographical information software ArcGIS 9.0.

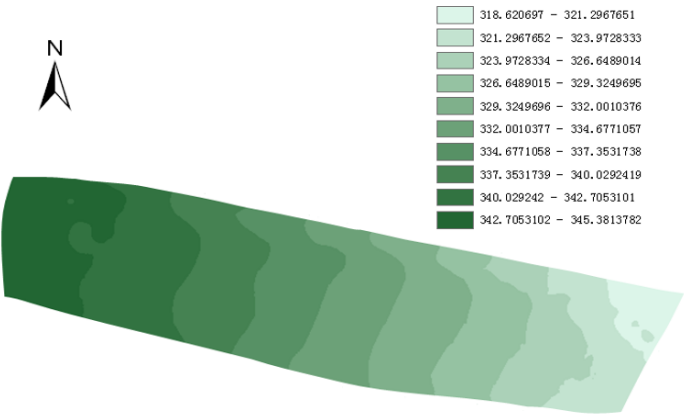


Fig.1 Elevation map of the experimental field

5. ANALYSIS ON THE SOIL MOISTURE DATA

5.1 Calculating the statistical eigenvalue of soil moisture speciality

In accordance with the classic statistical method, we calculated the statistical eigenvalue of evaluation data of soil moisture in the experiment land and its results are listed in Table 1. The average value of the measured soil moisture is 27.5%.The variance coefficients of these three moisture measurements are 119.2%,117.3%,127.6%. The classification of variance coefficient includes weak variability, $CV<10$;medieval variability $CV = 10\sim 100$; strong variability $CV>100$. The data indicate that soil moisture of this land attributes to Strong Variability.

Table 1 Statistical description of soil moisture

Date	Minimu m value	Maximal value	Average value	Standard value	Variance	Variance coefficien t
August 8,2006	0. 099	0. 45	0. 275	0. 351	0. 123	127.6

5.2 Testing normal distribution of soil moisture data

Testing normal distribution of soil moisture data was the precondition of using interpolation to analyze soil moisture feature data, because only the data distribution is normal, should interpolation be valid. Normal QQ plot is a statistical figure for testing normal data distribution. Given the sampling data is distributed normally, the sampling points should be a line in its normal QQ distribution plot. Besides, given the data is not shown in normal distribution, there will be a necessity to converse the data before the application of interpolation in order to be distributed normally.

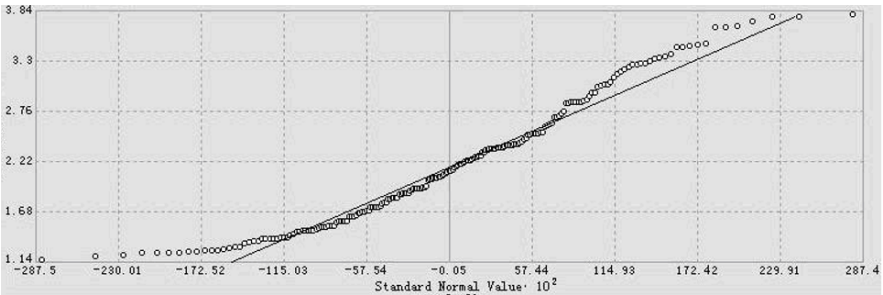


Fig.2 Normal QQ plots of soil moisture properties

The normal distribution of soil moisture feature was tested In ArcGIS, see Table 1. Results showed that most sampling points were distributed normally and the few sampling points departed far away from the straight line. After testing, all these data are eligible and can be interpolated.

5.3 Analyzing the spatial interpolation of soil moisture speciality

For describing true and intuitionistic spatial distribution of soil moisture, the research used Spatial Analyst module in ArcGIS 9.0, applied IDW、Spline、Kriging Interpolation to obtain the distributing map of soil moisture.

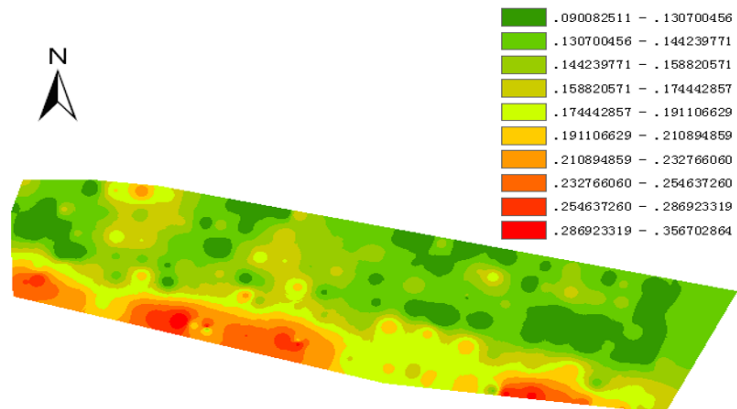


Fig.3 Map of soil moisture interpolated by IDW

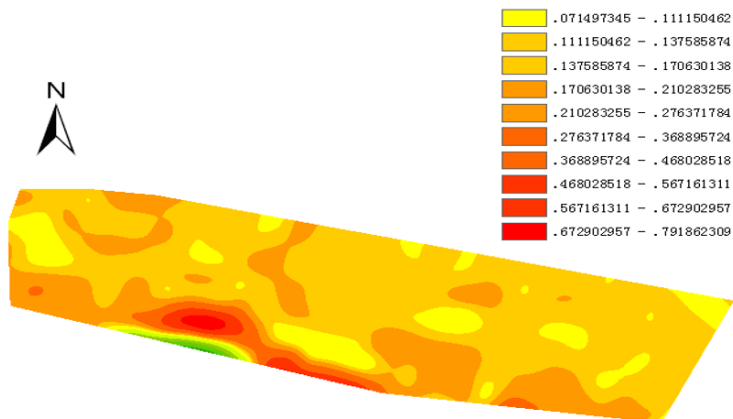


Fig.4 Map of soil moisture interpolated by Spline

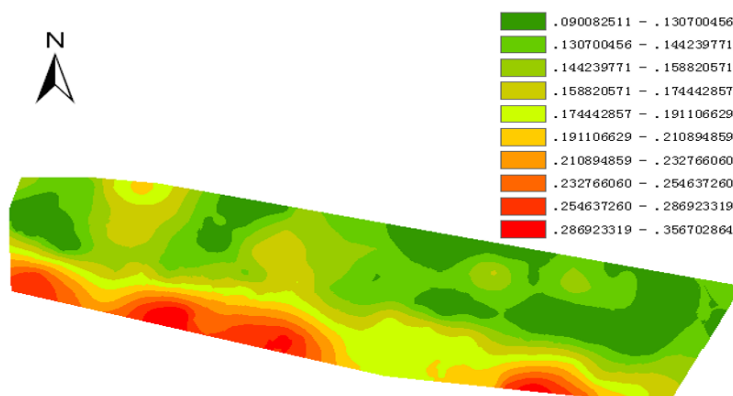


Fig.5 Map of soil moisture interpolated by Kriging

6. CONCLUSION

1) All of the soil spatial property is normal distribution and the spatial distribution of soil water property accord with the actual.

2) The three soil moisture graphs shows that soil moisture speciality distribution maps with the application of the three interpolation methods all effectively reflect the actual spatial distribution of soil moisture. The distribution of relatively high-value areas of soil moisture is almost consistent with that of relatively low-value areas, although there are differences in the spatial distribution maps of soil moisture because of the different mathematical principles applied.

3) with the application of IDW and Spline Interpolation methods, the soil moisture spatial distribution maps are characterized as spot-shape, discrete, and ,however, retaining the singular value (the specific maximum or minimum in local areas) of original estimate value, forming gradual island distribution around the center of the singular point. Kriging method, based on the trend of spatial changes of soil moisture property, could make proper modifications on singular value to avoid the impact of spatial distribution of variance on partial singular values.

4) Kriging method considers the randomness of the soil property as well as the structure of the soil property. It is the most appropriate mathematical method for the research on spatial variability of soil moisture. The spatial distribution map of soil moisture by Kriging interpolation is better to help researchers precisely and well understand the spatial distribution of the whole cropland soil moisture. Making a veracious spatial distribution map of soil moisture is of significance in promptly adjusting precise agriculture

management like fertilization and irrigation. It also offers the theoretical foundation for studying the connection between soil moisture and the yield.

5) When using spatial interpolation methods, it should choose the best method to get the most perfect effect of the spatial interpolation, the precondition is comparing the experimentations with the different actual instance of the experimental cropland and analyzing the actual metrical data of the sampling points adequately. The most importance was improving on interpolation methods, putting forward a new better scientific interpolation based on existing foundation.

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EXTRACTION OF REMOTE SENSING INFORMATION OF BANANA UNDER SUPPORT OF 3S TECHNOLOGY IN GUANGXI PROVINCE

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Abstract: This paper presents an automatic approach to planting areas extraction for mixed vegetation and hilly region, more cloud using moderate spatial resolution and high temporal resolution MODIS data around Guangxi province, south of China. According to banana growth lasting more 9 to 11 months, and the areas are reduced during crush season, the Maximum likelihood was used to extract the information of banana planting and their spatial distribution through the calculation of multiple-phase MODIS-NDVI in Guangxi and stylebook training regions of banana of being selected by GPS. Compared with the large and little regions of banana planting in monitoring image and the investigation of on the spot with GPS, the resolute shows that the banana planting information in remote sensing image are true. In this research, multiple-phase MODIS data were received during banana main growing season and preprocessed; NDVI temporal profiles of banana were generated; models for planting areas extraction were developed based on the analysis of temporal NDVI curves; and spatial distribution map of planting areas of banana in Guangxi in 2006 were created. The study suggests that it is possible to extract planting areas automatically from MODIS data for large areas.

Keywords: MODIS, 3S technology, banana, remote sensing information extraction

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1. INTRODUCTION

Banana is a monocotyledon which belongs to Musaceae from Musa. It is one of the four most famous fruits in the world. It has high yield, quick product, tastes good and crisp and rich nutrition. The banana output in china rank third in the world, and the planting area reached 80,000Ha in 2007. It is the second place in Chinese. Guangxi located in the area of low latitude (20o-27o) complicated geographic environment. Meteorological disaster such as frost injury, cold wave and drought could seriously affect banana production, especially in 2008. The most continuously lower temperature, rainy and snowy, freeze injury weather took place from on Jan 12th to Feb 12th in the southern of China. The disaster occurs once in fifty years. Banana and other sub-tropic crops were suffered injury severity. However, due to the laggard monitoring method and monitoring means, disaster loss evaluation had not been exactitude evaluated till on Apr 1st , 2008. The exactly and quickly evaluating disaster losing have become a focus issue for government .Planting spatial distribution information is key factor in quickly disaster losing evaluation. With the development of satellite remote sensing technology, extraction of remote sensing information of banana planting spatial distribution by using “3S” technology has become reality.

Guangxi Province is the second biggest region of banana planting in China. Taking banana planting of Guangxi Province as example, the article try to use MODIS data for extraction of remote sensing information of banana planting spatial distribution. The objective is to make better use of “3S” technology to serve the society.

2. METHODS

2.1 Study area and data source

This study area is located in Guangxi province, south of China. It's latitude is 20° 54' ~26° 23' N and longitude is 104° 29' ~112° 04' E, total area is 236700.0km². It belongs to monsoon region of south subtropical zone and north tropical zone without four clearly demarcated seasons of spring, summer, autumn and winter. The climate here is hot and humid in summer and warm and dry in winter.

Data input to the method is assumed to be calibrated and navigated level 1B radiance data which offered by National Satellite Meteorological Center and DVBS of GuangXi Institute of Meteorology. The time segment of

complete data is from 2002 to 2007. The MODIS data used to this method must be clear without cloud or little cloud images.

2.2 Extraction of remote sensing information method

Due to the relationship between vegetation indices calculated by different algorithms, reflectance of bands and field measurements of NDVI, we retrieve NDVI by using EOS/MODIS data. A NDVI retrieval model for study area can be established with this relationship. The specific flow chart of retrieval technique is shown as Fig. 1.

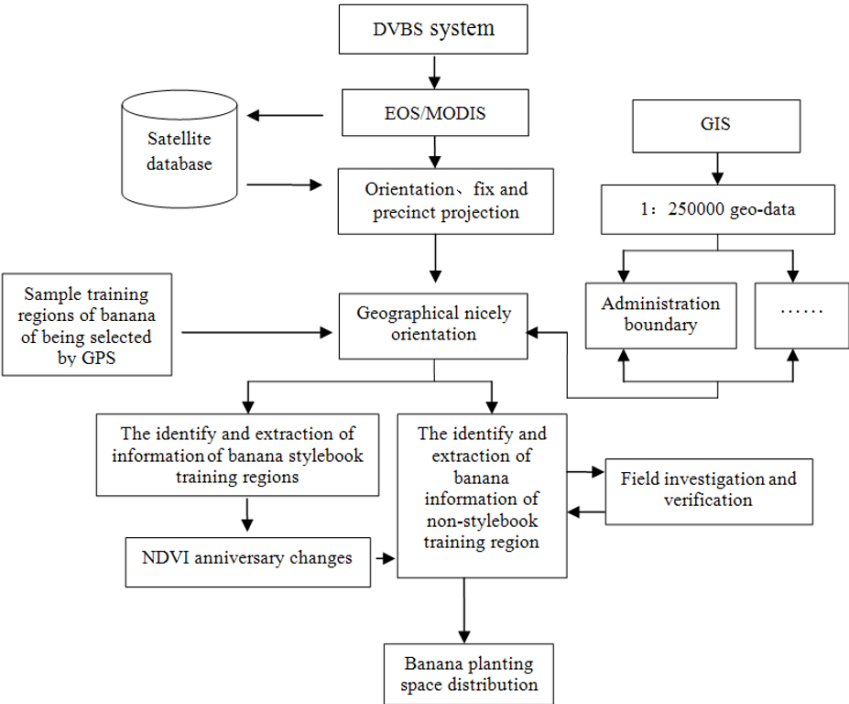


Fig. 1. The flow chart of the identify and extraction of banana planting space distribution information based on EOS/MODIS data

Based on the above flow chart of technique, detailed steps are described as follows:

(1)Inversing reflectance for EOS/MODIS imagery

The objective of atmospheric correction for EOS/MODIS data is to attain related parameters which can indicate the vegetation inherent properties of the region. Since the remotely sensed image was affected by reflective solar energy, solar elevation, zenith angle, the thickness of aerosol and the

bidirectional scattering due to the mutual influence of ground environment factors, we should take into account both atmospheric and bidirectional scattering to obtain accurate ground reflectance. Because the parameters of atmospheric profile based on measurements data or standard atmospheric profile were not established in China, in this paper we adopted international standard parameters of atmospheric profile to correct EOS/MODIS image.

(2) Obtaining characteristic parameters of vegetation

Due to the chlorophyll and inner architecture of foliage, a special reflective spectrum of vegetation foliage was formed like intensive absorption in the red waveband and intensive reflection in the near infrared waveband. Normalized difference vegetation index (NDVI) is chosen to obtain the vegetation coverage information from the satellite images. This index combines the algorithms of EVI, DVI and DDVI together with high fidelity of indicating the vegetation on the ground. It is one significant indirect index of the growth and number of vegetation and has a linear correlation with the vegetation coverage density. The formula is shown as:

$$NDVI = (NIR - RED) / (NIR + RED) \quad -1 \leq NDVI \leq 1 \quad (1)$$

In which NIR and RED represents the reflectivity of the vegetation coverage on the near-infrared band and red band respectively.

From the equation we can see that the water area and roadway area and city or town area, their value of NDVI are below 0 or approach constant value in different seasons. But the land surface with cover foliage, NDVI ranges from 0.1 to 0.7. NDVI has been applied in many fields, such as land cover or change, vegetation and environment change, net primary productivity and the assessment of crop yield.

(3) Sample training regions of banana of being selected by GPS

To the same foliage, its value of NDVI is various with its growth process. As result, the values of NDVI between foliages are diversity in different seasons. In order to mastery the spectrum characteristic of banana and distinguish banana from many kinds of foliages, some sample training regions of banana (the area must be bigger than 7 ha²) in different county of Guangxi were selected by GPS (the Global Positioning System).

(4) The identify and extraction of banana planting information based on EOS/MODIS data

In the first place, the values of NDVI of sample training regions of banana during the main growing seasons were calculated. As result, we could find the variety trend of curves of banana in regions being consistent (Fig.2).

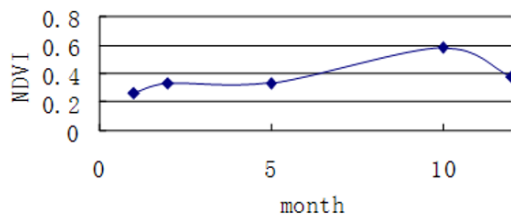


Fig2. The curse of NDVI of banana in Dacheng Town

Banana’s growth lasts more 9 to 11 months, the main of crops is banana in Guangxi province during winter, and the areas of banana cover are reduced during crush season. When the crush season was over, the values of banana planting areas approached zero.

The same time, corn and rice and soybean, theirs growth (from sowing to harvest) are general lasting 3 or 4 months. The south subtropical zone and north tropical zone forest growth lasting more than 12 months, but its value of NDVI anniversary approach constant. Consequently, the curves of NDVI variety in different foliages during the main growth seasons are difference. We can use the Maximum likelihood to extract the information of banana planting and its spatial distribution through the calculation of multiple-phase MODIS-NDVI from different foliages in Guangxi province. The result shows that the information of banana planting and its spatial distribution in 2006 were clearly in remote sensing imagine (Fig.3). The survey of field also showed that the information of banana planting based on multiple-phase EOS/MODIS data was highly reliable and truth.

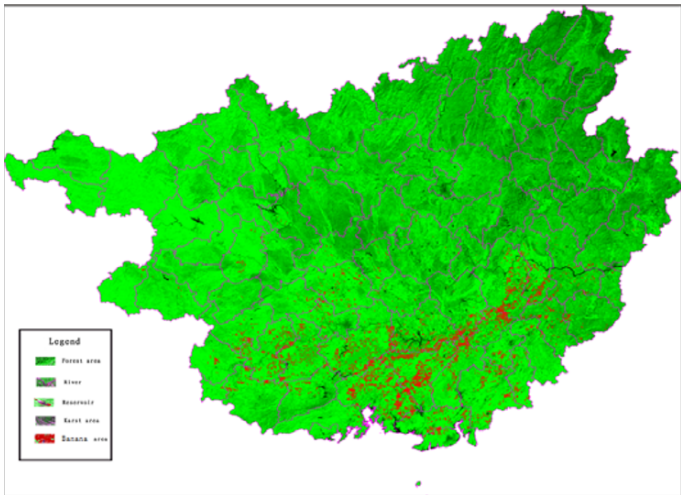


Fig3. the imagine of banana planting and its spatial distribution based on EOS/MODIS in Guangxi province

3. CONCLUSION AND DISCUSSION

Based on the above study and analysis, some conclusions can be drawn as follows:

(1) It is first used for extraction of banana planting spatial distribution information by using MODIS data.

(2) Method for extraction of banana planting spatial distribution information by using MODIS data is given in this paper.

(3) Decomposition of Mixed pixel is a difficulty points in calculating area of banana, so this paper does not calculate area of banana.

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THE EXPLOITATION OF WEBGIS BASED ON ARCGIS SERVER AND AJAX

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Abstract: It is an important to offer a user friendly interface in WebGIS. Excellent map services can be offered by ArcGIS Server. But the problem that the client fetches some data on a Web page from the server quickly is not solved well by ArcGIS Server, Ajax technology can overcome it. When getting large amount of data from server, It takes long time to parse the data for Ajax. To the study “Beijing Age-old Trees Management System”, the paper gives methods to solve two problems. Experiments show that the methods are feasible.

Keywords: ArcGIS Server, Ajax, WebGIS

1. INTRODUCTION

With the development of Internet, WebGIS plays an important role in people's lives. At present there are many WebGIS development platforms, such as SuperMap IS.net, ArcIMS and ArcGIS Server. ArcGIS Server is a new product of ESRI. It is a platform for building enterprise geographic information system (GIS) applications. It is powerful and it is easy to use.

As large amount of map data, there is the problem that transmits slowly on the Internet. Specially, when client requests information to server and get partial refresh page, server will transmit the whole HTML document of the page to client, it increases the response time. Ajax can solve the problem well. But when getting large amount of data from server, it takes long time

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to parse the data for Ajax. The paper studies solutions of the two problems and tests them in the “Beijing Age-old Trees Management System”. Experiments show that the methods are feasible.

2. KEY TECHNOLOGIES

2.1 ArcGIS Server

ArcGIS Server is a platform for building enterprise geographic information system (GIS) applications that are centrally managed, support multiple users, include advanced GIS functionality, and are built using industry standards. (ArcGIS Server Administrator and Developer Guide) Compared to other WebGIS develop platforms ArcGIS Server has some key features:

a. Standard GIS framework

ArcGIS Server provides a standard framework for developing GIS server applications. Its rich functionality allows developers to concentrate on solving organizational problems, not building GIS functionality from scratch.

b. Cost-effective deployment

ArcGIS Server supports enterprise applications, such as Web applications, running on servers, and supporting many users. The ADF runtime is not licensed. This allows multiple server applications to run on multiple Web servers.

c. Web controls

ArcGIS Server provides a set of Web controls. These Web controls simplify the programming model for including mapping functionality in your Web application, and allow developers to focus on more advanced GIS functionality aspects of their applications.

d. Web application templates

ArcGIS Server provides a set of Web application templates as a starting point for developers who want to build Web applications using the Web controls, and as an example of how to use the Web controls to build Web applications.

e. Cross-platform functionality

The ArcGIS Server ADF for Java runs on a variety of UNIX platforms and supports numerous Web servers. The GIS Server itself is supported on Windows, Sun Solaris, and Red Hat Linux. The ADF for .NET is available on a number of Windows platforms.

f. Cross-developer languages

ArcGIS Server supports a variety of developer languages for its use. This allows the objects to be programmed using a wide range of tools and should not require your programming staff to learn a new or proprietary language.

2.2 Ajax

Ajax (Asynchronous JavaScript and XML), is a group of inter-related web development techniques used for creating interactive web applications. (Wikipedia, the free encyclopedia) A primary characteristic is the increased responsiveness and interactivity of web pages achieved by exchanging small amounts of data with the server "behind the scenes" so that entire web pages do not have to be reloaded each time there is a need to fetch data from the server. This is intended to increase the web page's interactivity, speed, functionality and usability.

Ajax is asynchronous, in that extra data is requested from the server and loaded in the background without interfering with the display and behavior of the existing page. JavaScript is the scripting language in which Ajax function calls are usually made. Data is retrieved using the XMLHttpRequest object that is available to scripting languages run in modern browsers, or, alternatively, through the use of Remote Scripting in browsers that do not support XMLHttpRequest. In any case, it is not required that the asynchronous content be formatted in XML. So Ajax plays an important role in WebGIS.

3. PARTIAL REFRESH PAGES

Beijing is an ancient city; there are a number of old trees in Beijing. For visual managing and displaying on Internet, the frame of "Beijing Old-age trees management System" is as follow (Fig.1).

When client requests information to server and get partial refresh page, server will transmit the whole HTML document of the page to client, it increases the response time. For example, after user chooses query conditions and clicks "Query" button (it is showed in Fig.2), the entire page is reloaded, but some data are as same as before. It is not necessary for the data to be reloaded, it takes extra time. User hopes to get some data that are refreshed, for instance old-age trees information is showed in Fig.3, the others are not changed.

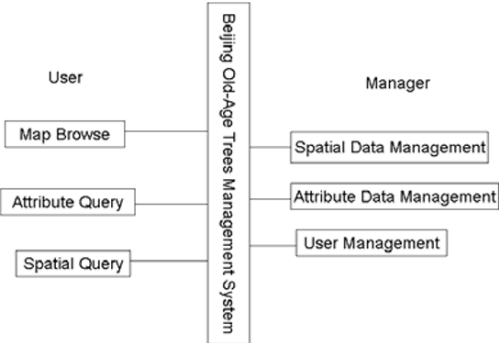


Fig 1. The frame of “Beijing Old-age trees management System”

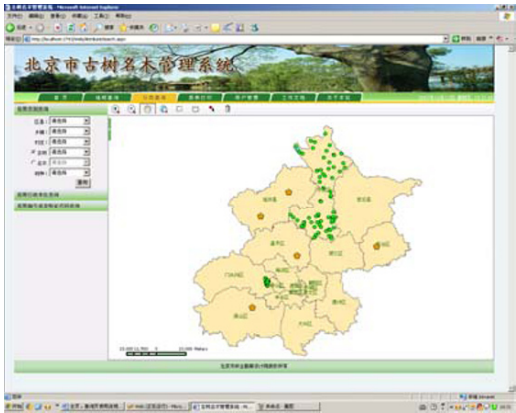


Fig 2. A querying page of “Beijing Old-age trees management System”

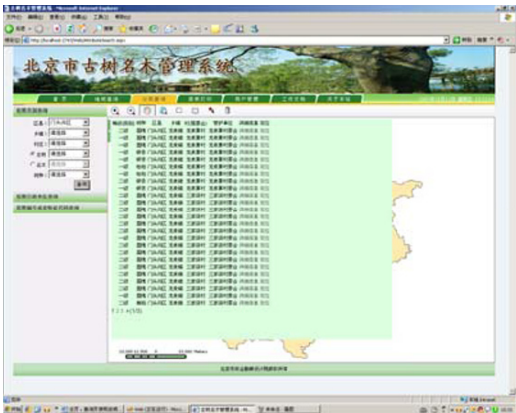


Fig 3. Querying results of “Beijing Old-age trees management System”

In order to solve the problem we apply AjaxPro.2.dll. AjaxPro.2.dll is the first free libraries which supports visiting servers by a variety of ways. We must follow three steps:

Step 1. Marking “[AjaxPro.AjaxMethod]” in front of calling database method. As follow:

```
[AjaxPro.AjaxMethod]
public static TreeClass GetTreeClass1(int code)
{
    return DataProvider.Instance().GetTreeClass(code);
}
```

Step 2. Adding following code in the configuration file:

```
<httpHandlers>
<add verb="POST,GET" path="ajaxpro/*.ashx" type="AjaxPro.AjaxHandlerFactory,
AjaxPro.2"/>
</httpHandlers>
```

The purpose to adding above code in the configuration file is to ensure that the request of client (Post and GET) can be intercepted by AjaxPro.AjaxhandleFactory.

Step 3. Adding following code while initializing page:

```
AjaxPro.Utility.RegisterTypeForAjax(typeof(the class name which contains the mothed))
```

The code can register the calling database method to the client so that the method can be visited at client.

4. HOW TO ENHANCE SHOWING SPEED

There are nearly 40,000 records in Beijing Old-age Management System database. Every query may refer hundreds or thousands records. So when the number of result data is large, it is a problem for the system to show the result quickly. Table1 shows the response time of the system when the query refers different number of records.

Table1. Query response time of the system by different number of records

Records Number	Response Time
800	2s
5000	18min

As Table 1 shows, when there are 800 records needed to be showed at client, it takes 2s, but when the records number increases to 5000, it takes 18 minutes. The big difference of the response time is because using Ajax.

The principle of Ajax is adding a middle layer called “Ajax Engine” between the client and the server. In this mode, not all the user requests are submitted to the server, only part of requests which really need server to

complete are sent to the server by the engine. The main functions of the engine include: capture browser events, initialize XMLHttpRequest object, send requests to the server, receive server response, and update client page. The information returned from “Ajax Engine” is normally formatted as text or XML. In our system most information uses XML to transmit data. So all the records returned from server are firstly formatted as XML, and then parse them at client. When the records number is low, it will take little time to format and parse. When data increase to a certain value, it will take huge system resources and time to convert and parse. It is why it takes 18 minutes to show 5000 records.

In order to reduce the response time we take two methods. One is reducing the information returned to the client; the other is that client’s showing program is implemented at server and server sends the result of the program running. Table2 shows the response time to display the same 5000 records.

Table2. Query response time on the two methods

Methods	Response Time
Reducing the information	4min
Writing displaying codes in server side	4s

Table 2 shows, reducing data amount can save a lot of time in showing data at client. Formerly we sent all the fields of a record back to the client, it takes 18 minutes, but now we only sent two fields back, it takes 4 minutes. It because when the system makes a XML sequence it must convert every field to a XML tag. After the client receiving the XML, firstly it explains all the XML tags, and then fetching the contents from the tags, finally it puts the contents into a string which HTML can recognize it. If there are many tags it will spend more time to make the string.

But there are two disadvantages in the method. One is it still takes 4 minutes to show data, the other is it losts some useful information. The other method is that client’s showing program is implemented at server and server sends the result of the program running. Table 2 shows that it only uses 4 seconds to show 5000 records. But there is a disadvantage in this method: when the user amount goes up, the weight of the server is increasing. So we must use different methods in different cases.

5. CONCLUSION

It is important to offer a user friendly interface in WebGIS. The paper discusses two problems. One is refreshing page partly; the other is how to enhance showing speed. It gives solutions of the problems and tests them in

“Beijing Old-age trees management System”. Experiments show that the methods are feasible.

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MONITORING FREEZE INJURY AND EVALUATING LOSING TO SUGAR-CANE USING RS AND GPS

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Abstract: From Jan 12th to Feb 12th, 2008, the most severity cold chilling and freeze injury weather took place during the last 50 years in the southern of China. Sugar-cane was suffered injury severity. However, the losing of sugar-cane which it was aroused by this weather disaster had not been exactitude evaluated till on Apr 1st, 2008. It was not only affected the sugar-cane ordinary harvesting and crushing, but also affected reserving sugar-cane seed for planting. Freeze injury is common disaster for sugar-cane in southern of China, and monitoring freeze injury using RS and GIS are of great economic significance, but little research work about it has been done in China. Freeze injuring is not only related to crop growth stage and the cold air intension from northern to southern and weather types, but also consanguineous related to land form and physiognomy and geographical latitude and height above sea level etc and crop planting spatial distribution. The case study of Guangxi province which is the biggest region of sugar-cane planting in China in this paper, the values of sugar-cane NDVI among the freeze injury occur former and after in early 2008 and without freeze injury occur in the same term 2007 were analyzed and compared based on the sugar-cane planting spatial distribution information which were carried out by using multi-phase EOS/MODIS data. The result showed that it was not only commendably reflected the spatial distribution of freeze injury but also reflected the sugar-cane suffered from degree using the values of sugar-cane NDVI of freeze injury occur former and after. The field sample investigation data of using GPS was integrated with the NDVI, the evaluation of region sugar-cane suffer from freeze injury losing could quickly and exactly realize.

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Key words: Cold Chilling, Freeze Injury, Sugarcane, Losing, RS, GPS, Evaluating.

1. INTRODUCTION

Weather disaster research focusing on disaster losing evaluation has long attracted the attention of the weather disaster community because disaster losing evaluation results are the basis for government officer anti-disaster and rescue disaster and rebuild after disaster. Scientists and practitioners have made great efforts in developing advanced disaster losing evaluation approaches and techniques for improving disaster losing evaluation accuracy (Yang Bangjie & Wang Maoxin etc, 2002, Zhang Xuefen & Chen Huailian, 2006). However, weather disaster losing evaluation remains a challenge because many factors, such as the complexity of the landscape and physiognomy in a study area, and crop spatial distribution, and weather disaster occurs and its continuance and intension spatial distribution, and experiment and knowledge of person who investigated crop suffering from weather disaster, may affect the accuracy of disaster losing evaluation. Although much previous research and some books are specifically concerned with disaster losing evaluation, a comprehensive up-to-date of disaster losing evaluation approaches and techniques is not available.

In view of the most severity continuance low air temperature and rainy and snowy freeze injury weather had taken place during the last 50 years in the southern of China since Jan 12th to Feb 12th, 2008. Sugar-cane and other sub-tropic crops were suffered injury severity. However, due to the disaster losing evaluation is a complex system that may be affected by many factors, and the methods of monitoring are draggle and the instruments of monitoring are lack, the losing of sugar-cane which it was aroused by this weather disaster had not been exactitude evaluated till on Apr 1st, 2008, It was not only affected the sugar-cane ordinary harvesting and crushing, but also affected reserving sugar-cane seed for planting, and the price of sugar once a time appeared abnormity wave in our country. Consequently, the exactly and quickly evaluating disaster losing have become a focus issue for government officer.

In this paper, the biggest province of sugar-cane planting in China was selected as the study area. The objectives of this research were to: (1) find out the way of identify and extraction of sugar-cane planting spatial distribution information in hilly, mixture vegetation and cloudy in 2007/2008 year crushing season, Guangxi; and (2) the retrieve a suitable monitor model for sugar-cane cold chilling and freeze injury based on EOS/MODIS data, and (3) find out a method of evaluation sugar-cane

disaster losing based on remote sensing and geographical information systems.

2. METHODS AND MATERIAL

2.1 Study area

The study area is located in Guangxi province, south of China. Its latitude is $20^{\circ}54' \sim 26^{\circ}23'N$ and longitude is $104^{\circ}29' \sim 112^{\circ}04'E$. Its total area is 236700.0 km^2 . It belongs to monsoon region of south subtropical zone and north tropical zone without four clearly demarcated seasons of spring, summer, autumn and winter. The climate here is hot and humid in summer and warm and dry in winter. For sugar-cane and other sub-tropic crops, however, Guangxi province is the region where the cold chilling and freeze injury occurs more frequently in winter than other provinces in China. For example, five times cold chilling and freeze injury disaster occurred in Guangxi province in recent decade. Among then, approach 90% counties of Guangxi province occurred severity radiate frost and freeze injury in 1999, and approach 55% to 60% counties of Guangxi province occurred severity radiate frost or freeze injury in 2001 and 2003 and 2004, and the most severity continuance low air temperature and rainy and snowy freeze injury weather occurred during the last 50 years from Jan 12th to Feb 12th, 2008.

In 2006/2007 year crushing season, sugar-cane planting area approach 853000 hm^2 , the yield of sugar over $7.08 \times 10^9 \text{ kg}$ in Guangxi province, which sugar yield approach 65% of the whole country. However, the sugar-cane planting area up to 95000 hm^2 , and the yield of sugar estimated approach $9.30 \times 10^9 \text{ kg}$ in 2007/2008 year crushing season.

2.2 Data acquisition

In this paper, EOS/MODIS imageries obtained from Dec 1st, 2006 to Feb 28th, 2008, whose path/row is 1151/1230. When the data was obtained, more than one county without cloud or little cloud images were selected, then they were synthesized one or more images in the same month. The weather and climate data were required from Guangxi climate center, and the sugar-cane suffered weather disaster field investigation data from Luzhai and Laibin and Longan and Tiandong counties where are the main sugar-cane planting region in Guangxi province.

2.3 Methods

Due to the relationship between vegetation indices calculated by different algorithms, reflectance of bands and field measurements of NDVI, we can retrieve NDVI using EOS/MODIS data. With this relationship, a NDVI retrieval model for study area can be established. A specific flow chart of retrieval technique is shown as Figure 1.

Based on the above flow chart of technique, detailed steps are described as follows:

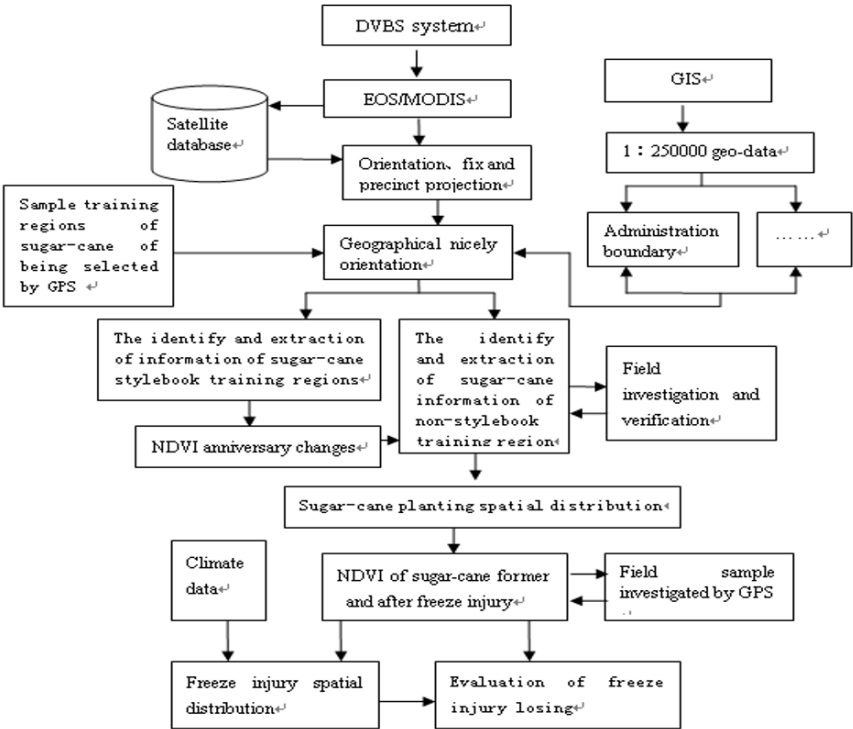


Fig1. The flow chart of the identify and extraction of sugar-cane planting space distribute information and evaluation of freeze injury losing based on EOS/MODIS data

Inversing reflectance for EOS/MODIS imagery

The objective of atmospheric correction for EOS/MODIS data is to attain related parameters which can indicate the vegetation inherent properties of the region. Since the remotely sensed image was affected by reflective solar energy, solar elevation, zenith angle, the thickness of aerosol and the bidirectional scattering due to the mutual influence of ground environment factors, we should take into account both atmospheric and bidirectional scattering to obtain accurate ground reflectance. Because the parameters of

atmospheric profile based on measurements data or standard atmospheric profile were not established in China, in this paper we adopted international standard parameters of atmospheric profile to correct EOS/MODIS image.

Obtaining characteristic parameters of vegetation

Due to the chlorophyll and inner architecture of foliage, a special reflective spectrum of vegetation foliage was formed like intensive absorption in the red waveband and intensive reflection in the near infrared waveband. By the reflectance difference varied in the red and the near infrared waveband, we can calculate related parameters that indicate the conditions of vegetated surfaces, such as normalized difference vegetation index (NDVI) which is a simple, effective and experiential measurement to vegetation activity. To some extent, NDVI indicates the vegetation information of status and succession.

NDVI, a parameter (range $-1 \sim 1$) denoting the ground vegetation coverage can be derived from the reflectance in the red and the near-infrared wavebands. This equation reads:

$$NDVI = \frac{\rho_{NIR} - \rho_R}{\rho_{NIR} + \rho_R}$$

From the equation we can see that in the water area and roadway area and city or town area, their value of NDVI are below 0 or approach constant value in different seasons. But for the land surface with cover foliage, NDVI ranges from 0.1 to 0.7. NDVI has been applied in many fields, such as land cover or change, vegetation and environment change, net primary productivity and the assessment of crop yield.

In addition, because of the value of NDVI will be change when crops suffer from weather disaster, we can compare the difference of NDVI former and after disaster to distinguish the spatial distribution of weather disaster intention and evaluate the losing of crops.

Sample training regions of sugar-cane of being selected by GPS

To the same foliage, its value of NDVI is various with its growth process. As result, the values of NDVI between foliages are diversity in different seasons. In order to mastery the spectrum characteristic of sugar-cane and distinguish sugar-cane from many kinds of foliages, some sample training regions of sugar-cane in different county of Guangxi were selected by GPS.

Field sample investigated by GPS to validate weather disaster intension

In order to validate weather disaster intension spatial distribution whether relate with the NDVI of former and later disaster difference size, some field sample investigating regions of NDVI difference size were selected by GPS in the main sugar-cane planting counties of Guangxi province.

The identify and extraction of sugar-cane planting information based on EOS/MODIS data

In the first place, the values of NDVI of sample training regions of sugar-cane during the main growing seasons were calculated. As result, we could find the variety trend of curves of sugar-cane in different regions being consistent.

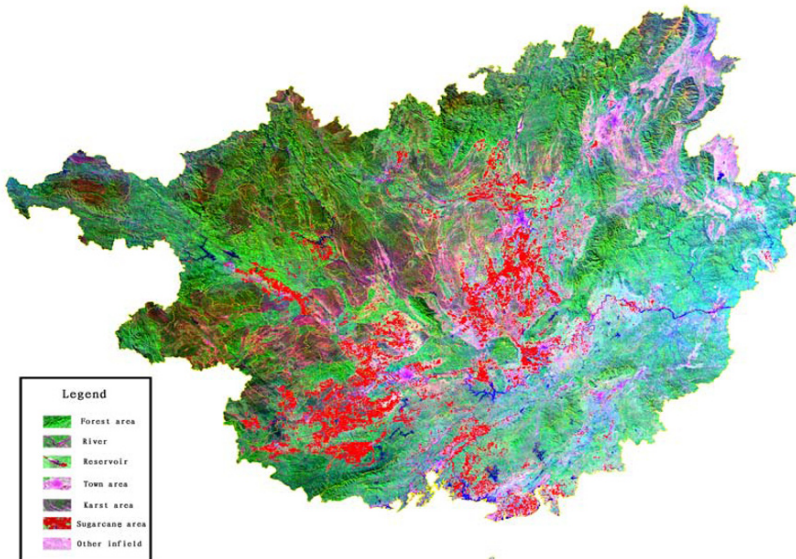


Fig.2. The imagine of sugar-cane planting and its spatial distribution based on EOS/MODIS in Guangxi province, 2007

For the sugar-cane, its growth lasting more 8 to 12 months, and the main of crops is sugar-cane in Guangxi province during winter, and the areas of sugar-cane cover are reduced during crush season. When the crush season was over, the values of sugar-cane planting areas approached 0.

And the same time, corn and rice and soybean, theirs growth (from sowing to harvest) are general lasting 3 or 4 months. The south subtropical zone and north tropical zone forest growth lasting more than 12 months, but its value of NDVI anniversary approach constant. Consequently, the curves of NDVI variety in different foliages during the main growth seasons are difference. We can use the Maximum likelihood to extract the information of sugar-cane planting and its spatial distribution through the calculation of multiple-phase MODIS-NDVI from different foliages in Guangxi province.

The result shows that the information of sugar-cane planting and its spatial distribution in 2007 were clearly in remote sensing imagine (Fig2). The survey of field also showed that the information of sugar-cane planting based on multiple-phase EOS/MODIS data was highly reliable and truth.

3. MONITORING FREEZE INJURY TO SUGARCANE BASED ON RS

Because of sugar-cane origins in the tropic region, its growth demands higher temperature. More than 50% sugar-cane area are distributed in the northern of sub-tropic in China, however, the air temperature of winter in the northern of sub-tropic is difficult to satisfy sugar-cane growth need. Lots of investigation and experiment data shows that sugar-cane physiological active will be limited when the air temperature approach to 4℃, and sugar-cane lamina chlorophyll contain will be violent descent and photosynthesis will be inhibited as soon as the air temperature drop to 0℃. If frost and freeze injury continuance, the lamina gradually turns to yellow and withered, and sugar-cane growth point and lateral bud emergence death, and stem of sugar-cane maybe appear water boil symptom and its organs maybe deterioration, and contain of sugar will drop and till the root lateral bud under soil emergence death. Consequently, the value of sugar-cane NDVI former and later frost (or freeze injury) must be changed. We can accord the spatial distribution of the value of NDVI former and later frost (or freeze injury) difference size to distinguish the spatial distribution of weather disaster intention.

In fact, we can see the value of sugar-cane NDVI between continuance low air temperature and rainy and snowy freeze injury weather former and later being distinctness discrimination from the table1.

Table1. sugar-cane NDVI of freeze injury former and later and without freeze injury based on sunny counties

	Guangxi		Laibin		Guigang		Liuzhou		Hechi	
	NDVI	%	NDVI	%	NDVI	%	NDVI	%	NDVI	%
Jan 4th, 2008	>0.3	53%	>0.3	21%	>0.3	28%	>0.3	27%	>0.3	60%
	0.2-0.3	45%	0.2-0.3	73%	0.2-0.3	65%	0.2-0.3	70%	0.2-0.3	39%
	0.0-0.2	2%	0.0-0.2	5%	0.0-0.2	7%	0.0-0.2	3%	00.-0.2	1%
Feb 15th, 2008	>0.3	4%	>0.3	0	>0.3	9%	>0.3	2%	>0.3	1%
	0.2-0.3	38%	0.2-0.3	24%	0.2-0.3	36%	0.2-0.3	52%	0.2-0.3	37%
	0.0-0.2	58%	0.0-0.2	76%	0.0-0.2	55%	0.0-0.2	46%	0.0-0.2	62%
Feb 4th ,2007	>0.3	30%	>0.3	12%	>0.3	28%	>0.3	4%	>0.3	5%
	0.2-0.3	64%	0.2-0.3	79%	0.2-0.3	65%	0.2-0.3	80%	0.2-0.3	68%
	0.0-0.2	6%	0.0-0.2	9%	0.0-0.2	7%	0.0-0.2	16%	0.0-0.2	27%

Compared the values of sugar-cane NDVI between cold chilling and freeze injury occur in early 2008 and without cold chilling and freeze injury occur in the same term 2007, it is not difficult to find the values of sugar-cane NDVI also being distinctness discrimination.

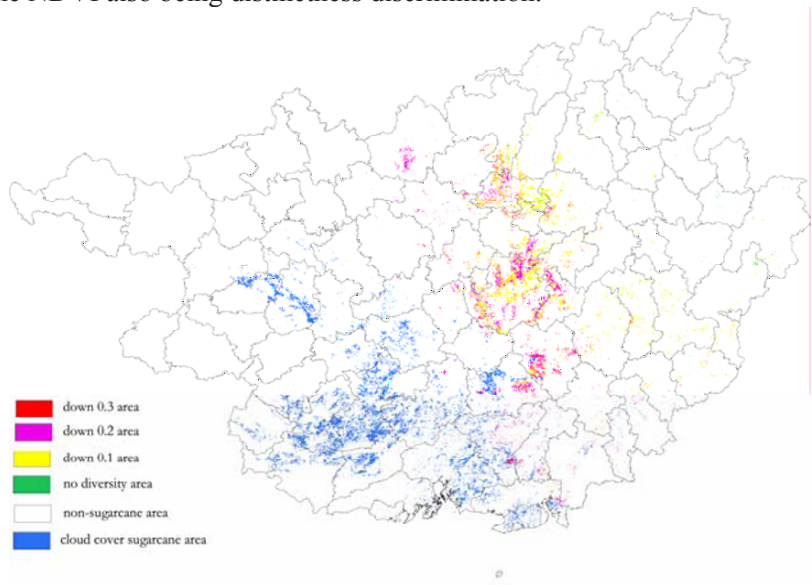


Fig3 the imagine of sugar-cane NDVI reduce after freeze injury

In order to find the relationship between sugar-cane NDVI difference size spatial distribution and weather disaster intension distribution, the difference of sugar-cane NDVI former and later freeze injury was calculated in this paper. From the figure 3, we can find the sugar-cane NDVI of later freeze injury descend is discrimination in different region. In view of sugar-cane breeds planting spatial distinction and the capability of sugar-cane breeds resist freeze injury, further more, colligating the climate data of freeze injury, we can judge the freeze injury intension spatial distribution.

4. LOSING OF SUGAR-CANE EVALUATION

Based on the sugar-cane NDVI difference size spatial distribute, some of samples sugar-cane NDVI difference size in Luzhai and Longan and Tiandong etc counties where the main sugar-cane planting regions of Guangxi province were selected from remote sensing imagine first, then according the result of classification to sample field investigate by GPS. The results showed that the sugar-cane NDVI difference size could reality reflect the disaster intension.

Table 3. area percent of sugar-cane NDVI different among freeze injury former and later and normal year in sunny region of Guangxi province, China

	NDVI difference	Guangxi	Laibin	Guigang	Liuzhou	Hechi
Difference of Jan,4th and Feb,15th, 2008	≤0	4%	1%	3%	6%	1%
	0.01-0.19	55%	58%	55%	65%	32%
	0.19-0.29	38%	40%	38%	29%	60%
	≥0.3	3%	0	4%	0	8%
Difference of Feb,4th ,2007 and Feb,15th, 2008	≤0	12%	4%	6%	23%	23%
	0.01-0.19	61%	64%	66%	72%	68%
	0.19-0.29	25%	32%	27%	5%	9%
	≥0.3	3%	0	2%	0	0

The results of sample field investigation showed that the NDVI difference decrease more than 0.30, sugar contain reduced 0.8% to 1.0%, if the NDVI difference decrease 0.2 ~ 0.3, the sugar contain reduced 0.5%, if the NDVI difference decrease 0.1 ~0.2, the sugar contain reduced 0.2%. Consequently, we can accord the area of percent of sugar-cane NDVI different to calculate the losing of sugar. In view of the sugar-cane planting area in 2007/2008 years crushing season in Guangxi province, the losing of sugar approach $2.56 \times 108\text{kg}$.

5. CONCLUSION

Based on the above study and analysis, some conclusions can be drawn as follows:

- (1) It is an effective way to reflect the spatial distribute information of cold chilling and freeze injury with using the changes of sugar-cane NDVI of former and after disaster based on the sugar-cane planting spatial distribution information which were carried out by using multi-phase EOS/MODIS data.
- (2) The field sample investigation data of using GPS was integrated with the changes of sugar-cane NDVI of former and after disaster, the evaluation of region sugar-cane suffer from cold chilling and freeze injury losing could quickly and exactly realize.
- (3) Monitoring cold chilling and freeze injury and evaluating losing of sugar-cane using Remote Sensing and Global Positioning System are great economic significance.

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ANALYSES ON REGIONAL CULTIVATED LAND CHANGE BASED ON QUANTITATIVE METHOD

Taking Reservoir Area of Three Gorges as Example

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Abstract: Three Gorges Project is the great project in the world, which accelerates economic development in the reservoir area of Three Gorges Project. In the process of development in the reservoir area of Three Gorges Project, cultivated land has become the important resources, a lot of cultivated land has been occupied and become the constructing land. In the same time, a lot of cultivated land has been flooded because of the rising of the water level. This paper uses the cultivated land areas and social economic indicators of reservoir area of Three Gorges in 1990-2004, takes the statistic analyses and example research in order to analyze the process of cultivated land, get the driving forces of cultivated land change, find the new methods to stimulate and forecast the cultivated land areas in the future, and serve for the cultivated land protection and successive development in reservoir area of Three Gorges. The results indicate as follow, firstly, in the past 15 years, the cultivated land areas has decreased 200142 hm², the decreasing quantity per year is 13343 hm². The whole reservoir area is divided into three different areas, they are upper reaches area, belly area and lower reaches area. The trends of cultivated land change in different reservoir areas are similar to the whole reservoir area. Secondly, the curve of cultivated land areas and per capita GDP takes on the reverse U, and the steps between the change rate of cultivated land and the change rate of GDP are different in some years, which indicates that change of cultivated land and change of GDP are decoupling, besides that, change of cultivated land is connection with the development of urbanization and the policy of returning forestry greatly. Lastly, the precision of multi-regression is

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lower than the BP neural network in the stimulation of cultivated land, then takes use of the BP neural network to forecast the cultivated land areas in 2005, 2010 and 2015, and the forecasting results are reasonable.

Key words: change of cultivated land; driving forces; theory of decoupling; BP neural network; Reservoir Area of Three Gorges

1. INTRODUCTION

Cultivated land is not only the precious natural resource and asset, but also is the important indicator for adjusting the national economy. It is significant to maintain some cultivated land at one period in one area (Jin Fengjun, 2006). Protecting cultivated land not only ensures the food production safety, but also protects eco-environment, so the quantity of cultivated land can affect the successive development in one area. There are many driving forces resulting in the cultivated land area reduction in China, such as, the policy of changing cultivated land into forestry, adjustment of agricultural structure, construction occupying the cultivated land and disasters destroying the cultivated land, at present, construction occupying has become the primary reason (Chen Baiming, 2006). The basic national situation in China is that the large population and the scarce cultivated land, which is determined that cultivated land protection and construction occupying cultivated land are contradictory all the time. At the beginning of economic construction in China, it was difficult to avoid economic construction occupying cultivated land, especially after reform and opening, the area of cultivated land decreased greatly, which aggravated the contradiction between cultivated land protection and construction occupying cultivated land gradually, the average reduction was $948.8 \times 10^3 \text{ hm}^2$ /year from 1996 to 2004, and construction occupying was $184.0 \times 10^3 \text{ hm}^2$ /year (Chen Baiming, 2006). Analyses the dynamic change of cultivated land and influential factors, which is helpful for using cultivated land purposely, fulfilling dynamic balance of cultivated land in one area, protecting successive development of dominant agricultural area and adjusting the relationship between cultivated land protection and economic development (Long Hualou, 2001; Bai Waiqi, 2004).

2. STUDY AREA

Three Gorges Reservoir Area is the reservoir flooding areas which are affected by the returning water after the Three Gorges Dam building and the migrated and removed areas, which lies in between the coordinates of longitude $106^{\circ}16'$ - $111^{\circ}28'$ E and latitude $28^{\circ}56'$ - $31^{\circ}44'$ N. The total area is $5.8 \times 10^4 \text{ km}^2$ and the population is 1.7×10^7 . The primary topography is mountains, which is 74% of total reservoir areas, hills is 22% of total reservoir areas and plains and dam lands are only 4% total reservoir areas.

3. DATUM AND METHODS

In this paper, the social economic datum from 1990 to 2004 are from Chongqing City Yearbook, Sichuan Province Yearbook and Yichang City Yearbook. The areas of cultivated land from 1990 to 2004 are from national modifiable survey. The traditional LUCC research minds are adopted in this paper, in the same time, some new theories and methods are used. Dynamic degree of single land use is taken to analyze the change speed of cultivated land in different counties. Correlation analysis is used to find the primary factors which affect the cultivated land change. Decoupling theory and Kuznets theory are adopted to research the relationship between cultivated land areas and GDP per capita. At last, the simulation precision comparison between BP neural network and multivariate regression linear is carried out, and use the higher precision methods to forecast cultivated land area.

(1) Change ratio per year means the situation of increasing or decreasing. The formula is following (1)

$$H = \frac{(U_b - U_a)}{U_a} \times 100\% \quad (1)$$

In the formula (1), H represents change ratio per year, U_a represents the area of cultivated land in the end of this year, U_b represents the area of cultivated land in the end of last year. If $H > 0$ means the area of cultivated land is decreasing, if $H < 0$ means the area of cultivated land is increasing, if $H = 0$ means the area of cultivated land doesn't change (Li Zhaofu, 2005).

Dynamic degree of single land use is introduced to indicate the change speed of cultivated land area in the research time (Wang Xiukan, 1998). The formula is following (2)

$$K = \frac{(U_b - U_a)}{U_a} \times \frac{1}{T} \times 100\% \quad (2)$$

In the formula (2), K represents the dynamic degree of cultivated land, U_a represents the area of cultivated land in the beginning of research, U_b represents the area of cultivated land in the end of research, T represents research time.

(2) In the research of relationship between cultivated land change and some social economic factors change, the editor chooses primary factors containing urbanization ratio, capital investment, savings of people, the first production value, the second production value, the third production value and meat production.

(3) Kuznets theory expresses the relationship between economic growth and income distribution (Zhou Jie, 2004), which takes on reverse U in the curve draft. Kuznets theory is introduced in this paper to illustrate the reverse U relationship between cultivated land areas and GDP per capita. Decoupling theory is introduced to analyze the relationship between cultivated land occupied and GDP growth (Chen Baiming, 2006). The experts of OECD environmental research field adopted decoupling theory to suggest the relationship between economic growth and environment pollution or indicate non-synchronism between economic growth change and environment pollution extent change. In their research process, they introduced decoupling ratio, decoupling index, absolute decoupling index and relative decoupling index (OECD, 2002). In this paper, change ratio per year of cultivated land area and change ratio per year of GDP are adopted to calculate decoupling ratio, decoupling index, absolute decoupling index and relative decoupling index. The formula is following (3)

$$A = \left| \frac{B}{C} \right| \bigg/ \left| \frac{B'}{C'} \right| \quad D=1-A \tag{3}$$

In the formula (3), A represents decoupling ratio, B represents change ratio per year of cultivated land area of this year, C represents change ratio per year of GDP of this year, B' represents change ratio per year of cultivated land area of last year, C' represents change ratio per year of GDP of last year, D represents decoupling index. If $0 < D \leq 1$ means relative decoupling index, which represents that the pressure of economic construction occupying cultivated land is little or change ratio per year of cultivated land and change ratio per year of GDP are non-synchronism. If $D \leq 0$ means absolute decoupling index, which represents that the pressure of economic construction occupying cultivated land is big or change ratio per year of cultivated land and change ratio per year of GDP are synchronism.

(4) In the research of cultivated land area simulation, the editor compares the precision of BP neural network and multivariate regression linear, at last the method of BP neural network is chosen in the cultivated land forecasting.

Multivariate regression linear is the method that finds the relationship of quantitative change between two dependant variables or more dependant variables and an independent variable (Yu Jianying, 2003). Neural network is a non-linear dynamic system and has higher ability in non-linear reflection, learning and correcting, which has unique superiority in solving non-linear questions. And Back-Propagation Network is short for BP neural network, which is used widely at present and embodies the elite of neural network (Chen Wei, 2005). In this paper, three layers BP neural network is used in simulating and forecasting the cultivated land change.

4. ANALYZE AND DISCUSS

4.1 Dynamic change of cultivated land area

The formula (1) is used to calculate the change ratio per year, the result is that, the area of cultivated land takes on decreasing trend from 1990 to 2004. During 15 years, the area of cultivated land decreased by 200142hm², the decreasing area per year was 13343 hm². From the change ratio per year, the extent of decreasing is not much, which takes on the trend, slow decreasing — dramatic decreasing — quite decreasing — dramatic decreasing — slow increasing. The years of dramatic decreasing are 1995 and 2002, and the change ratio per year are 4.77% and 9.50% respectively. The area of cultivated land is slow decreasing from 1996 to 1994, the average value of change ratio per year is 0.16%, the area of cultivated land is quite decreasing from 1996 to 2001, the average value of change ratio per year is 0.97%, the area of cultivated land has increasing trend from 2003 to 2004.

The formula (2) is used to calculate the dynamic degree of cultivated land and the results are divided into 5 grades. (0 , 1) means slow increasing, (-1 , 0) means slower decreasing, (-2 , -1) means slow decreasing, (-3 , -2) means quite decreasing and (-4 , -3) means dramatic decreasing. The dramatic decreasing areas concentrate in Jiangbei County, Banan County and Chongqing Construction area, slower decreasing areas distribute in Wanzhou County, Yunyang County, Fengjie County, Wushan County, Wuxi County, Badong County, Zigui County, Changshou County, Fengdou County, slow increasing areas distribute in Zhong County.

4.2 Driving forces of cultivated land change

Change of cultivated land is the most obvious pattern that human activities affect natural resources and environment, which is controlled by the area geography environment, including climates, physiognomies and soils and so on, on the other hand, which is disturbed by human activities and people choosing the manners of cultivated land used, including population distribution, traffic situation, social requirements and economic and industrious structures (Zhao Jie, 2004; Fan Hong, 2002). The research results indicated that the change of cultivated land area is attributed to the economic development and returning forestry policy during 15 years. In this paper, the editor pays attachment to discuss the change influenced by the adjustment of industrious structures and social economic activities. Correlation analysis is used in the SPSS 11.5 (Yu Jianying, 2003), and gets the correlations between the change of cultivated land area and the changes of some social economic indicator values. The result is following Tab.1. From Tab.1, the change of cultivated land area is highly closed to some social economic indicator values, which takes on minus correlation.

Tab 1. Correlation between cultivated land area and social economic indicators

	Urbanization ration	Capital investment	Savings of people	First production value	Second production value	Third production value	Meat production
Cultivated land area	-0.96 (**)	-0.97 (**)	-0.97 (**)	-0.84 (**)	-0.96 (**)	-0.97 (**)	-0.94 (**)

(**) Correlation is significant at 0.01 level (2-tailed)

4.2.1 Change of cultivated land area and economic development

The correlation coefficients between change of cultivated land area and change of the first production vale, change of the second production value and change of the third production value are -0.84, -0.96 and -0.97 respectively, and the minus correlation coefficients between change of the second production value, change of the third production value and change of cultivated land area are smaller than that of between change of the first production vale and change of cultivated land area, which indicates that industrious structures have been adjusted and the values increasing of the second industry and the third industry are at the cost of the decreasing of cultivated land area. In the same time, the correlation between change of the first production vale and change of cultivated land area is minus, which demonstrates that agricultural structures are changed, and the use of cultivated land is transferred into other uses which get more production value than that of cultivated land. Using GDP per capita represents the level of economic development in order to research the quantitative relationship

between the cultivated land area and GDP per capita. The change trait is similar as that of Kuznets curve (Cai Yinying, 2005; Zhang Zhengdong, 2005; Qu Futian, 2004), which takes on reverse U. From the trend, it reaches the peak in 1992 and descends from 1993 to 2003, which is like the part of reverse U. Then the curve is simulated with the statistics and the result is indicated as the equation (4)

$$Y=(10^{-6}) * X^3 - 0.0196 * X^2 + 42.319X + 962455 \quad R^2=0.9519 \quad (4)$$

In the equation (4), Y represents the area of cultivated land, X represents GDP per capita, and the adjustment value $R^2=0.9519$. It was the construction time of Three Gorges Project from 1990 to 2004, which affects the economy of Three Gorges Reservoir Area. In the process of economic development, a lot of cultivated land was occupied by the economic construction, which brings enormous pressure to the cultivated land protection, especially in this area where the cultivated land is scarce. The editor introduces the coupling theory in order to research the industry of cultivated land to the economic development. The decoupling index between the area of cultivated land and GDP value is calculated using formula (3). The fluctuation of change trend is frequent, which demonstrates that the synchronism ratio of cultivated land area change and GDP change is unstable. Some years are absolute decoupling, these years contain 1992, 1993, 1995, 1997, 1998, 2001, 2002, which indicates that the pressure of cultivated land occupied by economic construction was small relatively. The other years were relative decoupling and the pressure of cultivated land occupied by economic construction was big.

4.2.2 Urbanization and cultivated land change

Urban people growing brings on the urbanization acceleration, which results in the growth of urban inhabitancy and stimulates the need of industrial land. The correlation coefficient between urbanization ratio and cultivated land area is -0.96, which indicates that the decreasing of cultivated land area is close to the increasing of urbanization ratio.

4.2.3 Returning forestry policy and cultivated land change

A lot of cultivated land distribute on the hillside in Three Gorges Reservoir Area, most of them are on the hillside whose slope is bigger than 25° . The government appeals changing the cultivated land distributing on the hillside whose slope is bigger than 25° into forestry in Three Gorges Reservoir Area. It is the important project to change those cultivated land

into forestry, especially in the upper reach area and belly area. The policy carrying out is helpful for controlling soil losses and improving eco-environment, it is also useful for the agricultural adjustment and farmers income increasing. From Tab.1, cultivated land area and savings of people is minus correlation, and cultivated land area and meat production is also minus correlation, which demonstrates that the agricultural structures adjustment and farmers investment increasing are benefit from returning forestry policy. Wanzhou County, Kai County and Wulong County were made experiments for the returning forestry policy from 2000 to 2001. The area of returning forestry was $4.6 \times 10^4 \text{ hm}^2$ in these experimenting counties in two years. The decreasing area of cultivated land resulted from returning forestry policy was 68.08% in 2004 (Huang Juan, 2006).

4.3 Simulation and forecasting for the area of cultivated land

4.3.1 Simulation

In the process of simulation, BP neural network and multivariate regression linear are connected and compared. In this paper, three layers BP neural network is adopted. The neural units of input layer are the values of urbanization ratio, capital investment, savings of people, the first production value, the second production value, the third production value and meat production, the neural unit of output layer is the area of cultivated land and the number of neural units of covering layer is 9. Programming in the MATLAB6.5 environment, the training goal is 0.0002. At last, the training stops until 25824 epochs and reaches the goal. Then the areas of cultivated land of each year are simulated according to the BP neural network trained. Comparing the real values and simulating values, the editor finds that the change trend of real values and simulating values is consistent and the absolute error scale is distributing in (-2.50%, 2.50%). Above all, the simulation precision is high and the simulation result is reasonable. In the same time, the multivariate regression linear is used to simulate the relationship between the area of cultivated land and the values of some social economic indicators listed above (Wu Yi, 1995). The equation of multivariate regression linear is following (5)

$$Y = -240739X_1 - 0.044X_2 + 0.003X_3 - 0.096X_4 + 0.088X_5 - 0.039X_6 - 0.189X_7 + 1110829 \quad (5)$$

In the equation (5), Y represents the area of cultivated land, X_1 represents urbanization ratio, X_2 represents capital investment, X_3 represents savings of

people, X_4 represents the first production value, X_5 represents the second production value, X_6 represents the third production value and X_7 represents meat production, and the adjusting value R^2 is 0.967, and $F=22.261 > F_{0.001}$

(7, 5) = 8.10, and meets the regression requirement. Then using equation (5) simulates the area of cultivated land of each year. At last, the absolute error between real values and simulation value is distributing in (2.0%, 21.0%).

Comparing the absolute error of two simulated methods, the editor finds the simulation precision of BP neural network is higher than that of multivariate regression linear.

4.3.2 Forecasting

Using BP neural network trained forecasts the future area of cultivated land in the MATLAB 6.5 environment programming. The forecasting years are 2005, 2010 and 2015. The forecasting areas are 810500hm², 72800hm² and 726800 hm² respectively.

5. CONCLUSION

(1) Change of cultivated land area takes on the rule, slow decreasing—dramatic decreasing — quite decreasing — dramatic decreasing — slow increasing, and the change trend of cultivated land area per capita is similar to the total change trend of cultivated land area. The dynamic degree of cultivated land can be divided into five grades, they are slow increasing, slower decreasing, slow decreasing, quite decreasing and dramatic decreasing, and their spatial distribution are concentrated and most counties are in the state of slower decreasing. Besides, the change of cultivated land in three parts of the reservoir area is similar.

(2) Change of cultivated land area is highly closed to change of some social economic indicator values. The curve of relationship between cultivated land area and GDP per capita is similar to the Kuznets curve, which takes on reverse U. The synchronism ratio of cultivated land area change and GDP change is unstable, and some years were in the situation of absolute decoupling, and other were in the situation of relative decoupling, that is, the pressure of cultivated land occupied by economic construction was small relatively in some years, and others not. In the same time, urbanization and returning forestry policy resulted in decreasing of cultivated land area in fifteen years.

(3) The absolute error of two simulated methods is compared and finds the simulation precision of BP neural network is higher than that of multivariate regression linear. Using BP neural network forecasts the future area of cultivated land and forecasting results are reasonable.

Above all, the protection of cultivated land and economic construction is contradictory, and it is significant to fulfill the policy that change cultivated land on the hillside into forestry in Three Gorges Reservoir Area. Land use planning should aim at the benefits of cultivated land protection, economic construction and eco-environment improvement.

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RECONSTRUCTION OF 3D DIGITAL IMAGE OF WEEPING FORSYTHIA POLLEN

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Abstract: Confocal microscopy, which is a major advance upon normal light microscopy, has been used in a number of scientific fields. By confocal microscopy techniques, cells and tissues can be visualized deeply, and three-dimensional images created. Compared with conventional microscopes, confocal microscope improves the resolution of images by eliminating out-of-focus light. Moreover, confocal microscope has a higher level of sensitivity due to highly sensitive light detectors and the ability to accumulate images captured over time. In present studies, a series of Weeping Forsythia pollen digital images (35 images in total) were acquired with confocal microscope, and the three-dimensional digital image of the pollen reconstructed with confocal microscope. Our results indicate that it's a very easy job to analysis three-dimensional digital image of the pollen with confocal microscope and the probe Acridine orange (AO).

Keywords: confocal microscopy, pollen, 3D digital image, reconstruction

1. INTRODUCTION

Confocal microscope, which is one of the most exciting advances in optical microscope of the last century, has become a routine technique and indispensable tool for cell biological studies and molecular investigations

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(Lichtman, 1994). Confocal microscope works by exciting fluorescence with a highly focused beam of laser light. The light emitted from the point out-of-focus is blocked by the pinhole and can not reach the detector, which is one of the critical features of the confocal microscope. Thus only an image of the fluorescence from the focal plane is observed. In addition, the laser can scan over the sample from point to point and a single two-dimensional image of the optical section is obtained (Lichtman, 1994). In order to collect a series of images, the focus is shifted by a fixed amount. Then the object is scanned at the different Z position and the next image produced. The series of images are stored and the 3D data set is built. Thus a full three-dimensional image of the sample can be reconstructed via collecting a series of optical sections at different focal planes (Webb, 1999).

Using confocal microscopes, cells can be seen in three dimensions with much more clarity than previously possible. There have been numerous scientific papers employing confocal microscope in plant biology since it was first introduced, and this technology is very important for plant science researchers (Hepler and Gunning, 1998; Taira et al., 2004; Meckel et al., 2007; Cañamero et al., 2006). Since the advantage of confocal microscope is the ability to produce 3-dimensional reconstructions of specimens as mentioned above, the aims of the present studies is to reconstruct 3D image of Weeping Forsythia pollen with confocal microscope.

2. MATERIALS AND METHODS

2.1 Plant material and reagents

Pollen was collected from the Weeping Forsythia plants grown in Shandong University of Technology. Acridine orange (AO) was purchased from Molecular Probes (Eugene, OR, USA). Barley pollen was placed in a 200ml micro-centrifuge tube and 20ml of 20 μ M AO was added. The micro-centrifuge tube was incubated in dark at 4°C for 1h followed by incubation at 20°C for 1h in dye free solution.

2.2 Laser scanning confocal microscopy

The pollen was observed with a 40 $\times$ water immersion lens (NA = 1.2, Leica) and the images was captured by a confocal microscope, the microscope equipped with a 10 $\times$ ocular lens. A laser-scanning confocal microscope (Leica TCS SP2, Germany) with an air-cooled, argon-ion laser as the excitation source at 488nm was used to view the pollen. The images of

pollen were detected in the yellow channel. Moreover, the channel settings of pinhole, detector gain, amplification offset and gain, and laser transmission were adjusted to provide an optimal balance of fluorescence intensity of the targeted pollen and background. Data were collected by a computer attached to the instrument, stored on the hard drive, processed with a Leica TCS Image Browser, and transferred to Adobe Photoshop 6.0 for preparation of figures.

2.3 Three-dimensional pollen images reconstruction

A series of pollen images (35 images in total) were acquired with the laser-scanning confocal microscope, and the software of Leica TCS SP2 is used to reconstruct three-dimensional images of the sample.

3. RESULTS AND DISCUSSION

Confocal microscope, which is a major advance upon conventional microscope, has been used in a number of scientific fields (Michalet et al., 2003). Using confocal microscope, one can visualize deep into cells and create images in three dimensions (Hibbs, 2000). Compared with conventional microscopes, confocal microscopes have some distinct advantages. Confocal microscope has a higher level of sensitivity, because it has highly sensitive light detectors and the ability to accumulate images (Rawlings and Byatt, 2002). In addition, the resolution of images can be improved by eliminating out-of-focus light (Rawlings and Byatt, 2002).

There have been numerous scientific studies employing confocal microscope in pollen research. Confocal microscopy was used for morphological analysis and imaging purposes to organic-walled microfossils from the Middle Jurassic (Feist-Burkhardt and Pross, 1998). Yamaoka and Leaver (2008) reveal that mitochondrial morphology is influenced by MIRO1 and plays a vital role during embryogenesis and pollen tube growth with laser confocal microscopy. McInnis et al (2006) investigate reactive oxygen species and NO accumulation with confocal microscopy using ROS probes DCFH2-DA and DAF-2DA, respectively.

It has been shown that confocal microscope is a very important tool in the morphological analysis of fossil palynomorphs such as pollen, spores and dinoflagellate cysts without special sample preparation (Feist-Burkhardt and Pross, 1998; Feist-Burkhardt and Monteil, 2001; Hochuli and Feist-Burkhardt, 2004; Thouand et al., 2005). In present studies, a series of Weeping Forsythia pollen digital images (35 images in total) were acquired with confocal microscope (Fig.1). Furthermore, the three-dimensional digital

image of the pollen was reconstructed with confocal microscope software, and the clear 3D image of the pollen was acquired (Fig.2). It has been found that AO is the most popular fluorochrome for studies on whole blood, reticulocyte counting, and identification of nucleic acids (Anderson, 1957; Armstrong, 1956, 1957). Here we applied AO to dye the pollen of Weeping Forsythia, and the clear 3D image of the pollen was acquired. Our results indicate that it's a very easy job to analysis pollen with confocal microscope and probe AO.

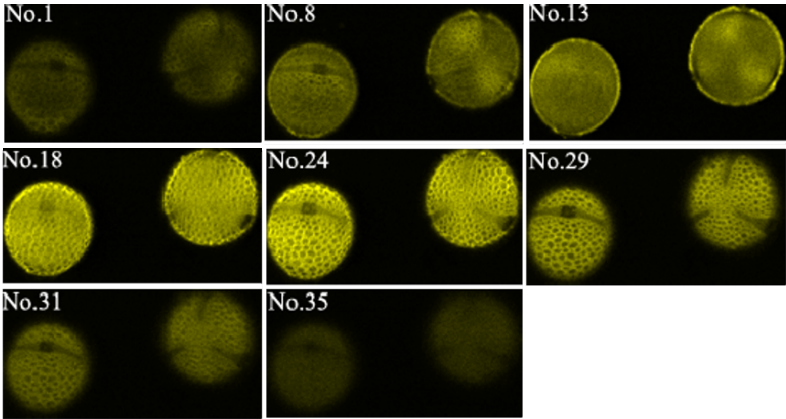


Fig.1. A series of confocal microscope digital images of Weeping Forsythia pollen. Pollen was labeled with AO. Thirty-five images were acquired with the laser-scanning confocal microscope, and eight images (from No.1 image to No.35 image) were chosen in the figures. (×400).

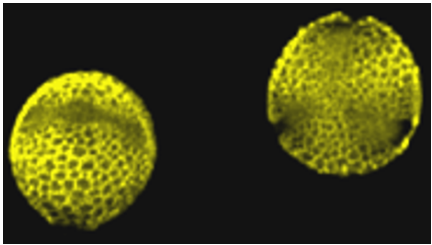


Fig.2. A full three-dimensional digital image of the pollen was reconstructed with confocal microscope software. (×400)

4. CONCLUSION

Confocal microscope, which is a major advance upon conventional microscope, has been used in a number of scientific fields. Using confocal

microscope, one can visualize deep into cells and create images in three dimensions. Our results indicate that it's a very easy job to analysis three-dimensional digital image of the pollen with confocal microscope and probe Acridine orange (AO).

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STUDY AND DEVELOPMENT OF MOBILE TRACING TERMINAL BASED ON GPRS FOR AGRICULTURAL PRODUCTS QUALITY TRACKING

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Abstract: Traceability system has become an important means for food safety management. Global food industry and many countries have paid increasing attention to the construction of food traceability system, but rarely referred to tracing terminal. According to the technical requirements of cereal and oil products quality safety tracing process, we design and develop a mobile tracing terminal based on GPRS for agricultural products quality tracking to facilitate quality supervisors and consumers to track and trace the quality of related agricultural products anytime ,anywhere.

Keywords: cereal and oil products; quality tracking, GPRS; tracing terminal; embedded software; microelectronics

1. INTRODUCTION

The quality safety of agricultural products influences consumers' benefit. To carry on the research on key technology for quality tracking and tracing in the full supply chain of food production, inspection, storage, processing, and transportation, will contribute a lot to stabilize national cereal safety,

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improve agricultural products quality safety management system, and protect consumers' rights.

Traceability depends on the terminals. The mobile tracing terminal based on GPRS(General Packer Radio Service) provides an effective traceable means for quality supervision departments through the internet or wireless network. Taking advantage of the technology, like electronic label, bar code and digital document management, we can track the agricultural products quality information about food production, supply, sale, storage, etc, strengthen the real-time monitoring and checking of the quality information, and improve full-supply-chain quality information management, which will play an important role in establishing a mechanism for agricultural products quality information acquisition and interaction.

2. MAIN RESEARCH CONTENT

2.1 Construction of hardware platform

Constructing a hardware platform is the basis of mobile tracing terminals, and needs the support of the specific, strong low-level hardware to develop the platform's functions. The hardware platform aims at the research and design of GPRS wireless data transmission module's peripheral circuit, the interface between GPRS module and monolithic processor, between bar code scanner and monolithic processor, between LCD(Liquid Crystal Display) and SCM(Single Chip Microcomputer), between keyboard input and SCM. In order to strengthen the system's expansibility, we also extend the COM and USB interface. The architecture is shown in Fig1.

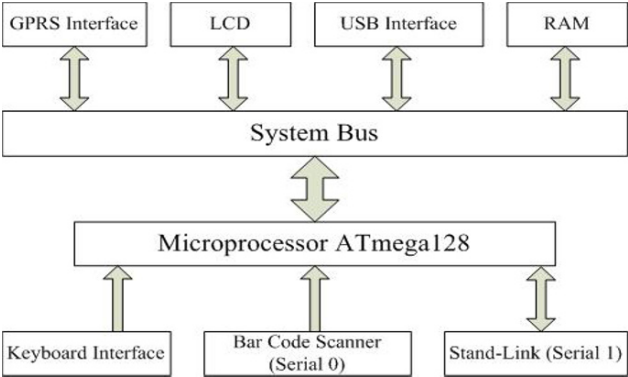


Fig 1: The architecture of hardware platform

2.2 Application and design of embedded software system

The application and design of embedded software system contains the design of embedded operating system uC/OS-II for software module between bar code scanner and SCM, interface driver between GPRS module and SCM, and low-layer driver for USB devices.

3. IMPLEMENTATION OF MOBILE TRACING TERMINAL

The mainboard of the hardware consists of two parts: GPRS MODEM module and tracing module at the core of monolithic processor.

3.1 GPRS MODEM Module

Because the data sent to the remote server only contains the traceable code, and the data received from server only includes key quality information, so the data is very small and cannot reduce the data transmission speed through GPRS.

Based on SIM300, produced by SIMCOM, we design the peripheral circuit to implement GPRS wireless receiving and sending module. The module can be used separately or integrated with tracing module. The design electronic principle of the module is shown in Fig2-3.

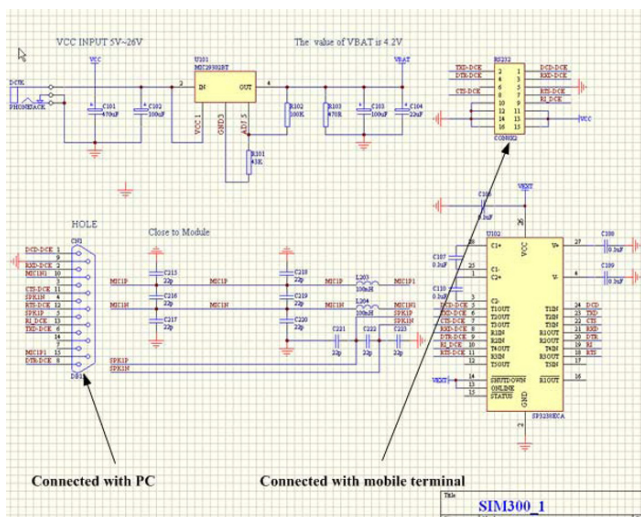


Fig2: GPRS MODEM electronic principle

- (1) 32K RAM: 0000000H-7FFFFFFH
- (2) LCD: A000H-A001H
- (3) GPRS interfaceSC16C550: B000H-B007H
- (4) USB bus interfaceCH375: C000H-C001H
- The electronic principle is shown in [Fig4-6](#).

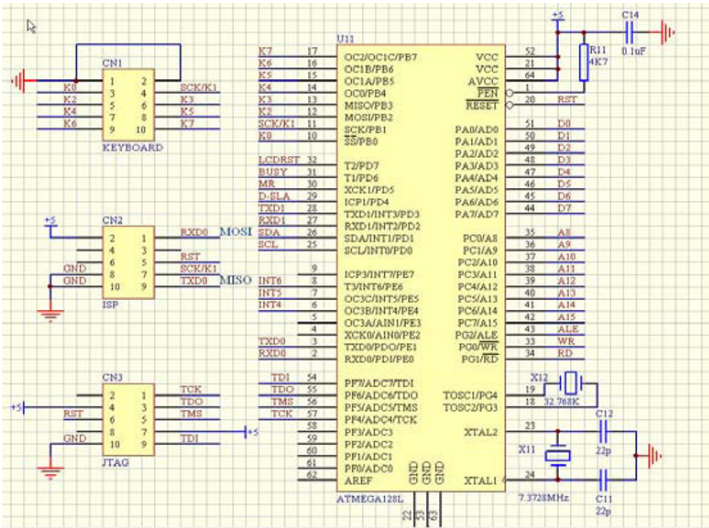


Fig4: MCU electronic Principle

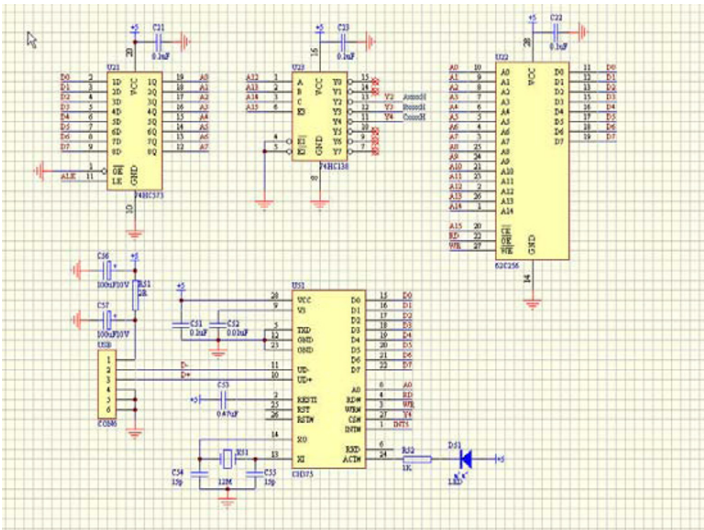


Fig5: Address decoding, 32K RAM and USB interface circuit

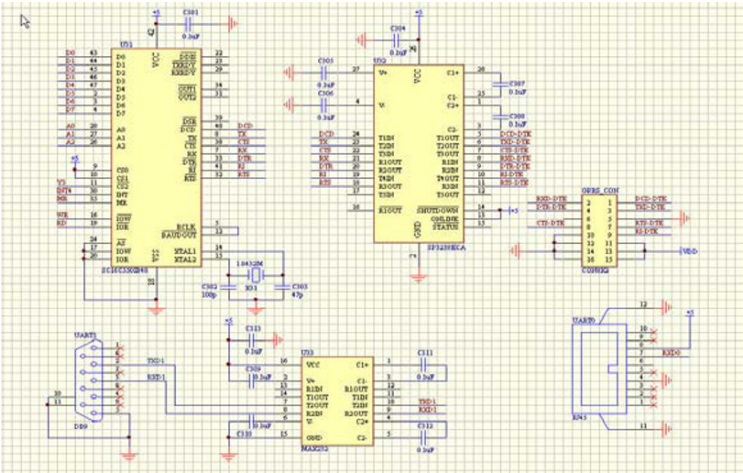


Fig6: MODEM and Serial circuit

4. SOFTWARE PROGRAMMING FOR TRACING TERMINAL

Software programming, implemented by ICCAVR, mainly consists of five modules: Initial setting of MCU, Functions related to GPRS operation, function set achieving display of LCD, low-layer driver of USB interface chip and task decomposition of uC/OS-II embedded operation system. Tracing process is illustrated in Fig7.

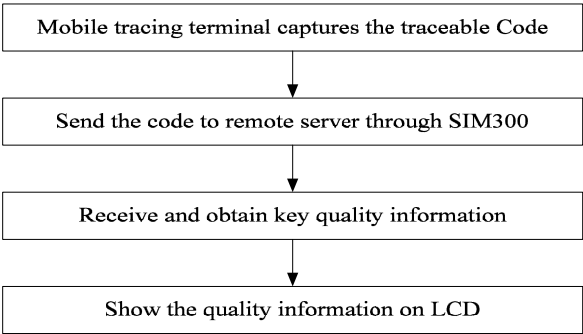


Fig 7: Tracing information process

4.1 Functions related to GPRS operation

The implementation of mobile tracing terminal for agricultural product quality tracking, based on GPRS, depends on SIM300 which is

manufactured by SIMCOM. The connection between SIM300 and MCU is completed via UART (Universal Asynchronous Receiver Transmitter). The essence of microprocessor dataflow operation is to achieve the data exchange based on GPRS through the serial that expands the function of modulation and demodulation TCP/IP is embedded in SIM300, so SIM300 can send the data to serials and activate corresponding commands. SC16C550 contains the following functions:

```
void Init_SC550(void) //16C550initial function, BaudRate=115200
void SC550_Write_Register( unsigned char address, unsigned char val )
//write commands into register 16C550
void SC550_Send_Char(unsigned char tc) //write single-byte data
void String_Send( char *send_buff ) //write string
unsigned char SC550_Read_Char(void) //write single-byte data
void String_Read( char *read_buff ) //write string
```

In order to achieve network data transmission based on TCP/IP by SIM300, we should take the following steps:

Firstly, tracing terminal, as the client, sends a TCP connection request to remote server. The specific command is: AT+CIPSTART="TCP", "Server's IP Address", "Server's Port".

Secondly, If the network is connected successfully, the server will return "CONNECT OK". Then we can send traceable data to remote server by the command "AT+CIPSEND", and the module will automatically receive it via certain serial. We can also close the TCP connection by the command "AT+CIPCLOSE".

Main functions contain:

```
void TCP_Connect( void ) //achieve TCP connection
unsigned char* TXD_Reply( unsigned char *tx_str, unsigned char
*reply_str )
void TCP_Connect( void ) //specific program
{
    // AT command
    unsigned char con_cmd0[] = "AT\r";
    unsigned char con_cmd1[] =
"AT+CIPSTART=\\"TCP\\",\\"211.147.18.79\\",1433\r";
    unsigned char con_cmd2[] = "AT+CIPSEND\r";
    unsigned char con_cmd3[] = "AT+CIPCLOSE\r";
    // SIM300 respond
    unsigned char ans0[] = "\r\nOK";
    unsigned char ans1[] = "CONNECT OK";
    unsigned char ans2[] = ">";
    unsigned char ans3[] = "SEND OK";
    unsigned char ans4[] = "CLOSE OK";
    //send data
```



```

    unsigned char data[] = "CAAS_AII| traceable code\x01a";
    if( (TXD_Reply( con_cmd0,ans0 ))==0) // Catch Exception
    if( (TXD_Reply( con_cmd1,ans1 ))==0) // Catch Exception
    if( (TXD_Reply( con_cmd2,ans2 ))==0) // Catch Exception
    if( (TXD_Reply( data,ans3 ))==0) // Catch Exception
    if( (TXD_Reply( con_cmd3,ans4 ))==0) // Catch Exception
}

```

4.2 Low-layer driver of USB interface chip

CH375 is the interface chip of USB-HOST. It can not only define Host mode, but also Device mode. Moreover, the two modes can be dynamically exchanged to each other. Here we define it as Host mode. Under Host mode, CH375 can be used to connect with U-Disk or data capturing device with USB interface. Functions contain:

```

void CH375_WR_CMD_PORT(UINT8 cmd) //write commands into CH375
void CH375_WR_DAT_PORT( UINT8 dat ) //write data into CH375 port
UINT8 CH375_RD_DAT_PORT( void ) //read data from CH375 data port
void CH375HostInit( void ) //initiate CH375
unsigned charmInitDisk( void ) //initiate U disk
void RD_USB_DATA(void) //read data from U disk

```

5. DISCUSSIONS

1 Recently, taking the monolithic processor as the core, and researching the application of GPRS technology on tracing cereal and oil products are not very popular. According to the requirements of research subject, we design and develop the mobile tracing terminal based on GPRS for agricultural quality tracking.

2 The application of RFID on cereal products quality safety traceability is still a problem, mainly owing to the characteristics of cereal packing and transportation. So it is still hard to solve, and needs many more tentative researches on the application of RFID during cereal dispersive storage and transportation, even if we have prepared stand-link interface for RFID identifying device.

3 Our research result is demonstrated well only in some small areas, and has not been widely applied. With the countries and markets' increasing requirements of agricultural product quality safety standards, we can improve the tracing terminal technically.

ACKNOWLEDGEMENTS

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GIS-BASED ELABORATE SPATIAL PREDICTION OF SOIL NUTRIENT ELEMENTS USING ANCILLARY TERRAIN DATA IN CHONGQING TOBACCO PLANTING REGION, CHINA

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Abstract: The precision agriculture hopes to manage the variation in soil nutrient status continuously, which requires reliable predictions at places between sampling sites. For the long time, ordinary kriging has been used as one prediction method when the data are spatially dependent and a suitable variogram model exists. However, even if data are spatially correlated, there are often few soil sampling sites in relation to the area to be managed. Recently, Digital elevation models (DEMs) and remotely sensed data are becoming more readily available, these data are usually far more intensive than those from soil surveys. If these ancillary data are coregionalized with the sparse soil data, they might be used to increase the accuracy of predictions of the soil properties.

Under ArcGIS platform, this paper employed spatial predictions of the soil total N, P, K in Chongqing tobacco planting region, China, with cokriging and regression kriging respectively. For the both, intensive terrain data including elevation, slope and aspect were used with the soil data. Traditional ordinary kriging (OK) was investigated as comparison basis to determine which approach is appropriate for different soils properties mapping. And the results suggest that the use of intensive ancillary data can increase the accuracy of predictions of soil properties in arable fields provided that the variables are related spatially.

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Keywords: Ordinary kriging, Cokriging, Regression kriging, Ancillary terrain data, Soil nutrient elements, Elaborate spatial prediction

1. INTRODUCTION

One aim of regional precision agriculture is to use information about spatial distribution of soil properties to manage the field in a landscape-specific way, for example, by the application of nutrients at the places and in the amounts required (Sylvester-Bradley et al., 1999). Sampling at discrete places is the traditional means of obtaining information about the soil properties. However, field surveys are often time-consuming, labor-intensive and costly although it is still the dominant way to obtain information about most soil properties. Predicting unsampled sites by available sampling points data with acceptable precision and cost hence has been the focus of pedometrics (Webster, 1985; Cambardella et al., 1994; Goovaerts, 1997; McBratney et al., 2000; Auemhammer, 2001). Traditionally, this has been achieved by classification, but it has been known for some time that this approach does not describe adequately the variation that scientists and farmers are aware of intuitively (Webster and Oliver, 2001). Ordinary kriging (OK) is quite suited to this problem provided that the data are spatially dependent (Webster and Oliver, 2001). However, the data from soil surveys, are often sparse even though they might be spatially autocorrelated and it can lead to considerable uncertainty in the kriging prediction (McBratney et al., 2000). Also, the precision of the prediction was shown to be very sensitive to the density of observation points and the gains in precision were only slight for sites located near from the observation sites (Auemhammer, 2001).

A way of refining these predictions could be to use easy-to-measure auxiliary data describing landscape features. Particularly, the use of attributes derived from Digital Elevation Models (DEMs) which becomes more readily available looks promising since some researchers have demonstrated the relationships between landform features and soil properties (Chaplot et al., 2004; Lopez-Granados et al., 2005; Kay and Rainer, 2008; Wu et al., 2008). Recently several predictive soil attributes techniques that use intensive auxiliary data also have been developed, for example, cokriging and regression kriging.

Chongqing tobacco planting region, which locates in one of the poorest areas of southwest China and mostly is covered by hilly and mountains. Understanding how soil nutrients vary across landscape positions especially increasing the accuracy of spatial prediction of soil nutrient elements would be of huge economic and environmental benefit for local tobacco planting

and management. This study predicted spatial distribution of total N, P, K of this region by cokriging and regression kriging respectively in which intensive terrain properties including elevation, slope and aspect were used as auxiliary data. Traditional ordinary kriging interpolation was investigated as comparison basis to determine which approach is the appropriate method for different soil nutrient elements spatial distribution.

This paper is organized as follows. Following the introduction, theory and methods used in this study are described in section 2. The study area and data are depicted in section 3. In section 4, results and discussion are illustrated. Conclusion is finally made in section 5.

2. THEORY AND METHODS

Ordinary kriging, cokriging and regression kriging were used in this study. The last two are described briefly below (for ordinary kriging, see (Webster and Oliver, 2001))

2.1 Cokriging

Cokriging is an extension of ordinary kriging that takes into account the spatial cross-correlation from two or more variables. The usual situation is one where the primary or target variable, $Z_u(x)$, has been measured at many fewer places, x , than the secondary one, $Z_v(x)$, with which it is coregionalized. We assume that they obey the intrinsic hypothesis. Both variables have an autovariograms, for variable u , this is

$$\gamma_{uu}(h) = \frac{1}{2} \left[\{z_u(x) - z_u(x+h)\}^2 \right] \quad (1)$$

Where h is a vector, the lag. For v also, the expected differences are zero and its autovariogram is $\gamma_{vv}(h)$. The two variables have a cross-variogram, $\gamma_{uv}(h)$, defined as

$$\gamma_{uv}(h) = \frac{1}{2} E[\{Z_u(x) - Z_u(x+h)\}\{Z_v(x) - Z_v(x+h)\}] \quad (2)$$

Which describes the way in which u is spatially related to v .

To compute the usual cross-variogram, there must be sites where both u and v have been measured, i.e., collocated. The experimental cross-variogram, $\hat{r}_{uv}(h)$ can be estimated by

$$\hat{\gamma}_{uv}(h) = \frac{1}{2m(h)} \sum_{i=1}^{m(h)} \{z_u(x_i) - z_u(x_i + h)\} \{z_v(x_i) - z_v(x_i + h)\} \quad (3)$$

Where z_u and z_v have been measured at sites x_i and $x_i + h$, and $m(h)$ is the number of pairs of data points separated by the particular lag vector h .

The cross-variogram can be modeled in the same way as the auto-variogram, but there is an added condition. Any linear combination of the variables is itself a regionalized variable, and its variance must be positive or zero. This is ensured if we adopt the linear model of coregionalization. For any pair of variables u and v , the variogram is

$$\gamma_{uv}(h) = \sum_{k=1}^k b_{uv}^k g_k(h) \quad (4)$$

Where the b_{uv}^k are the variances, for example the nugget and sill variances. $g_k(h)$ is the spatial autocorrelation function which must be the same for both variables being analyzed.

The ordinary punctual cokriging prediction of the primary variable, Z_u is obtained from the linear sum

$$\hat{Z}_u(x_0) = \sum_{i=1}^V \sum_{l=1}^{n_l} \lambda_{il} z_l^{ok}(x_i) \quad (5)$$

Where there are V variables, $l=1,2,\dots,V$, of which u is the one to be predicted, and the subscript i refers to the sites of which there are n_l in the search neighborhood where the variable l has been measured. The λ_{il} are the weights, which in the case of 'classical' cokriging (Goovaerts, 1997) satisfy

$$\sum_{i=1}^{n_l} \lambda_{il} = \begin{cases} 1, & l = u \\ 0, & l \neq u \end{cases} \quad (6)$$

There are the non-bias conditions, and subject to them the weights, λ_{il} , that minimize the estimation variance of $\hat{Z}_u$ for a point, x_0 , are found by solving the kriging system for all $v=1,2,\dots,V$ and all $j=1,2,\dots,n_v$. The weights λ_i are inserted into Eq.(5) to estimate $\hat{Z}_u(x_0)$.

2.2 Regression kriging

Odeh et al. (Odeh et al., 1995) describe three types of regression kriging: model A, B and C which are developments of the general theme. For this study, we used model C, which we summarize here. The method is based on a linear regression between a target variable such as certain soil property (Z), and a secondary or third variable, such as elevation or slope (Y_i). The regression model so obtained is used to predict Z to the locations of the

prediction grid at which Y_i is known. The residuals from the regression ε are kriged to the prediction grid using the variogram computed from the residuals. The predicted values $\hat{Z}_R$ and the kriged values of the residuals $\hat{\varepsilon}_{ok}$ are summed to give the predicted values of the target variable $\hat{Z}_{RK}$.

$$\hat{Z}_{RK}(x)=\hat{Z}_R(x)+\hat{\varepsilon}_{ok}(x)$$

(7)

2.3 Performance evaluation indicators

In order to evaluate the performance of different spatial prediction methods, mean squared error(MSE) and root mean squared standardized effect(RMSSE), in this paper are used as performance measure indicators.

The mean squared error(MSE) is expressed as

$$MSE=\frac{1}{l}\sum_{j=1}^l[z_1(x_i)-z_2(x_i)]$$

(8)

The root mean squared standardized effect(RMSSE) is expressed as

$$RMSSE=\sqrt{\frac{1}{l}\sum_{i=1}^l[z_1(x_i)-z_2(x_i)]^2}$$

(9)

Where $z_1(x_i)$ is standardized site true value and $z_2(x_i)$ represents standardized site prediction value, l is the number of validation sites. When MSE is more close to 0 and RMSSE more approaches 1, the accuracy of prediction is hold higher.

3. THE STUDY AREA AND DATA SOURCES

3.1 The study area

The study area is located in the east part of Chongqing between north latitudes 28° 09' and 32° 12' and east longitudes 106° 23' and 110° 11' (Fig.1).The climate is characterized by an average annual temperature between 10.1 and 18.2°C .Annual precipitation is about 1200mm. According to Chinese Soil Taxonomy, the soils are classified by yellow soil, yellow brown soil, limestone soil, purple soil and paddy soil.

The landform of study area is dominated by hills, low mountains and medium mountains. Generally, it is undulating with slopes ranging from 0 to 84 ° and altitudes within the range from 100 to 2750.92 m. Due to weak transportation and economy development, tobacco planting is one of local dominant crops productions.

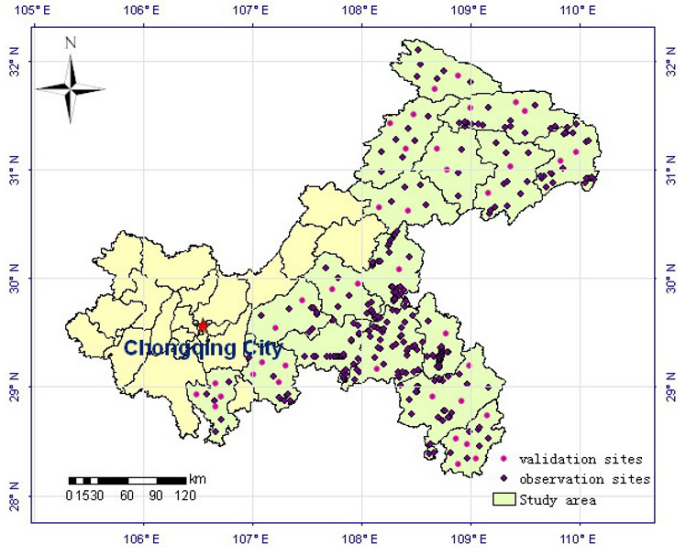


Fig.1: Location of the study area

3.2 Data sources

The soil was sampled in the spring of 2007 at 300 sites of 17 tobacco planting counties at a depth of 0-20cm. The position of each site was georeferenced using a DGPS(Differential Global Positioning System). From the observations, 40 sites, randomly selected, were kept aside for validation(the validation set).Therefore, the 260 remainder sites formed the prediction set.

The field soil was analyzed for total Nitrogen(N),Phosphorus(P) and K₂O as soon after sampling as possible. Kjeldahl method was utilized to measure the soil total N , and the total P and K₂O were determined by x-ray fluorescence(XRF) analysis(Lu and Yang, 1993) .

A DEM was constructed using ArcMAP Version 9.2(ESRI). 50×50m DEM data were derived from automated image matching of scanned panchromatic aerial photograph based on AUNDEM(Auemhammer, 2001) . Primary terrain attributes including elevation, slope and aspect were extracted by ArcMAP spatial analyst module.

4. RESULTS AND DISCUSSION

4.1 Exploratory data analysis

Table 1 list the descriptive statistics of total N,P and K₂O in the study area. The K-S test indicates that the whole dataset all followed a normal distribution.

Table 1. Descriptive statistics for Total N,P, K₂O

Item	Mean	Min	Max	Skewness	S.D	K-S
Total N(ug/g)	1534.40	798.64	2933.	0.89	356.70	0.21
Total P(ug/g)	717.50	299.10	1448.90	0.78	202.34	0.17
Total K ₂ O(%)	2.41	0.68	5.66	0.65	0.74	0.15

The Pearson product moment correlation coefficients were calculated between the total N,P, K₂O and elevation, slope and aspect from the co-located data to determine whether it was feasible to use these terrain data to improve their prediction. Table 2 gives the correlation coefficients of N,P and K₂O with terrain data. For all three soil nutrients, they all related to elevation and ranged from weak for K₂O,to moderate for P and strong for N. For slope, both N and P were inversely related but K₂O is likely to be indirect. Besides K₂O, the other soil elements have no obvious links with aspect.

Table 2. Pearson product moment correlation coefficients between soil nutrients and terrain data

Item	Elevation	Slope	Aspect
Total N	0.295*	0.173*	-0.026
Total P	0.179*	0.116*	-0.051
Total K ₂ O	0.113*	0.075	-.132*

4.2 Cokriging

Experimental cross- and auto-variograms were obtained by applying Eq.(4) using the DEM predictions of elevation, slope and aspect at the observation sites. We fitted the models of coregionalization to soil total N,P, K₂O and three terrain attributes. It is shown as in table 3.

It was indicated that the two sets variograms of elevation, slope for N and P were both bounded and were fitted by exponential, spherical ,Gaussian, spherical function respectively. The variograms of aspect for N and P were unbounded, whereas it it was bounded for K₂O with the range set to

121.04.Under the ArcGIS platform, elevation, slope were associated as covariances for N,P spatial prediction and elevation, aspect act covariances for K₂O spatial prediction. The whole prediction maps were shown in Fig.2.

Table3 Varioram model parameters with elevation, slope and aspect of soil nutrients

Item	Variable	Model	Nugget	Sill	Range(Km)
N	Elevation	Exponential	0.69	0.90	141.163
	Slope	Spherical	1.13	1.21	320.606
	Aspect	Linear	1.21		
P	Elevation	Gaussian	0.71	0.88	118.198
	Slope	Spherical	1.13	1.21	320.606
	Aspect	Linear	1.21		
K ₂ O	Elevation	Exponential	0.61	0.89	117.379
	Slope	Linear	0.71		
	Aspect	Spherical	0.62	1.01	121.04

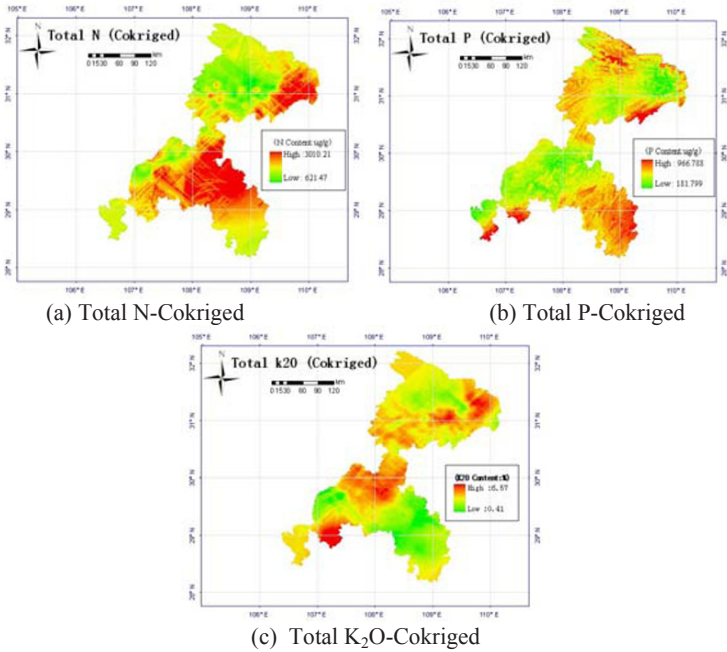


Fig.2 Spatial distribution for total N, P,K₂O with cokriging

4.3 Regression kriging

Linear regressions of total N,P, K₂O were done on the DEM data at the observation sites. The equations were depicted as follows:

$$Y_1 = 0.482h + 1.8\alpha - 0.151\beta + 128.067 \quad (r^2=0.635) \tag{10}$$

$$Y_2 = 0.32h + 0.751\alpha + 0.205\beta - 263.189 \quad (r^2=0.517) \tag{11}$$

$$Y_3 = 0.001h + 0.003\alpha - 0.001\beta + 2.254 \quad (r^2=0.611)$$

(12)

where Y_1, Y_2 and Y_3 represents total N, P, K_2O respectively, h, α, β represents elevation, slope and aspect.

An experimental variogram was also computed on the residuals of total N, P and K_2O from the regression at each site. It is shown as table 4.

Table 4 Parameters for the fittest residuals theoretical models of total N,P, K_2O

Item	Model	Nugget	Sill	Range(km)	C/C ₀ +C	R ²
N residuals	Spherical	7.94	10.99	211.40	0.72	0.872
	Exponential	6.05	10.61	114.601	0.57	0.958
	Gaussian	7.11	10.41	75.820	0.68	0.811
P residuals	Spherical	11.77	29.49	81.259	0.40	0.672
	Exponential	4.94	29.68	78.022	0.17	0.713
	Gaussian	15.23	29.53	72.210	0.52	0.966
K_2O residuals	Spherical	0.15	0.23	72.651	0.65	0.753
	Exponential	0.12	0.24	57.718	0.50	0.821
	Gaussian	0.16	0.23	54.479	0.70	0.934

It was found that the highest determined coefficient(R^2) existed in Exponential, Gaussian, Gaussian Model for total N,P, K_2O residuals respectively. The whole spatial prediction map is displayed in Fig.3.

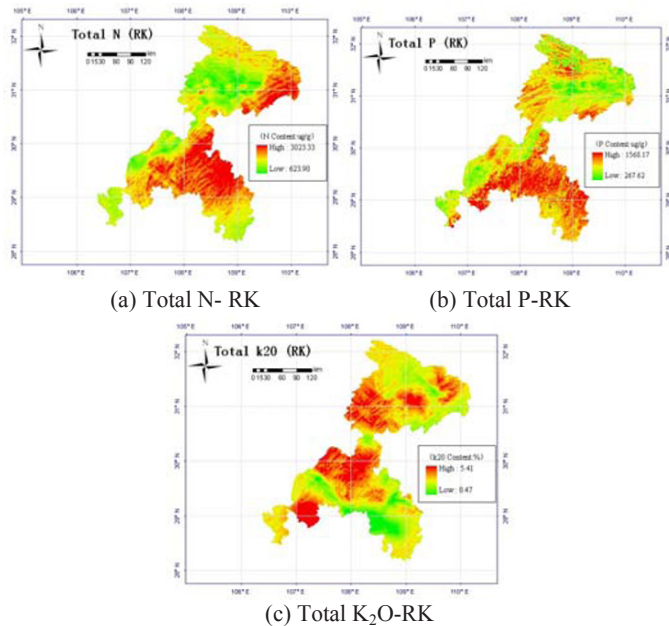


Fig.3 Spatial distribution for total N, P, K_2O with regression kriging

4.4 Ordinary kriging

Different semivariogram models for models for the soil N,P,K₂O were presented in Table 5.

Table 5 Parameters for the fittest residuals theoretical models of total N,P,K₂O

Item	Model	Nugget	Sill	Range(km)	C/C ₀ +C	R ²
N	Spherical	0.94	1.29	11.811	0.73	0.731
	Exponential	0.77	1.31	10.235	0.59	0.742
	Gaussian	1.02	3.85	10.496	0.26	0.867
sP	Spherical	2.39	4.50	10.983	0.53	0.821
	Exponential	1.89	4.53	11.378	0.42	0.910
	Gaussian	2.74	4.51	9.437	0.61	0.877
K ₂ O	Spherical	4.91	5.68	121.766	0.86	0.726
	Exponential	4.11	5.63	63.034	0.73	0.891
	Gaussian	4.73	5.62	58.767	0.84	0.677

It was found that the highest determined coefficient(R²) existed in Gaussian, Exponential, Exponential Model for total N,P, K₂O respectively. The whole spatial prediction map is displayed in Fig.4.

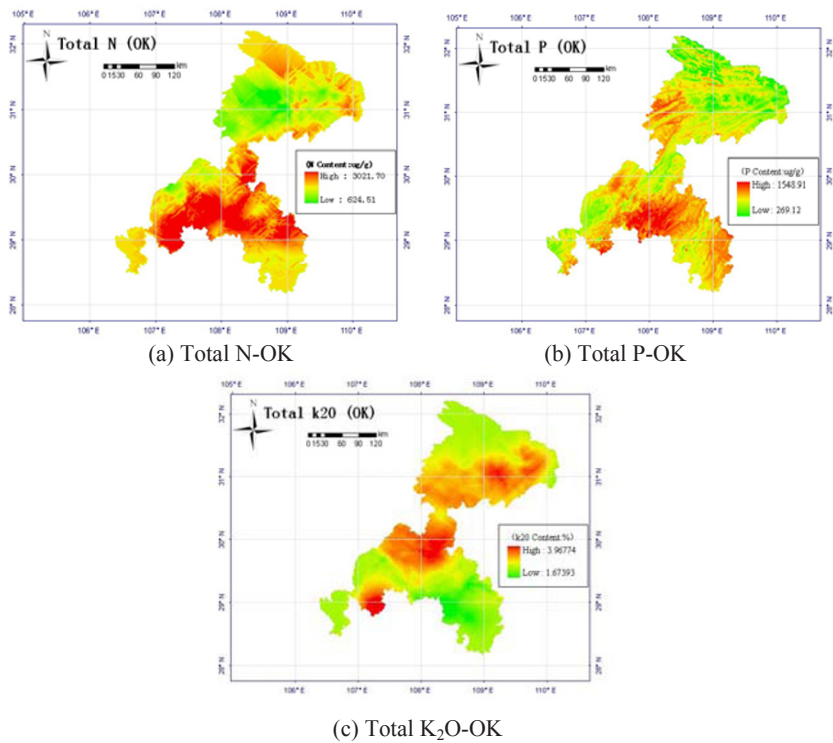


Fig.4 Spatial distribution for total N, ,K₂O with ordinary kriging

4.5 Discussion

The MSEs and RMMSEs for total N,P, K₂O are given in table 6 for each method of spatial prediction.

Table 6 MSE and RMSSE between the measured and predicted values at the validation sites

Item		CoK	RK	OK
N	MSE	0.065	0.047	0.091
	RMSSE	0.872	0.911	0.811
P	MSE	0.071	0.082	0.102
	RMME	0.946	0.901	0.777
K ₂ O	MSE	0.034	0.027	0.061
	RMSE	0.911	0.973	0.897

For total N, the MSE for regressing kriging was the smallest, followed by that for cokriging, and last was the ordinary kriging. The RMSSE of being close to 1 is ranked by RK,CoK and OK. These results show that that some benefit aroused from using the more intensive terrain data to predict the sparser soil properties.Fig.2,3,4 shows the spatial prediction maps with different methods. Generally, the major patterns of variation are evident but the detail is different. The most variable map is the one from the OK prediction, and the smoothest is from regression kriging.

Table 6 shows that CoK was the most accurate method of prediction for total P, followed by regression kriging, and the ordinary kriging was the worst in this case. The less accurate predictions from regression kriging probably reflect regression model less good determined coefficient .

For total K₂O ,the prediction accuracy rank shows similar pattern with total N.

5. CONCLUSION

Understanding the spatial variation of soil properties to mange the field is one aim of precision agriculture. Increasing the accuracy of the spatial predictions of soil nutrient elements with the aid of available ancillary data is quiet economic and environmental typically in complex terrain hilly areas ,because soil nutrient elements are measured sparsely compared with ancillary data such as elevation, slope and aspect. This study predicted the three soil nutrient elements spatial distribution with CoK, RK and OK in Chongqing tobacco planting area, and the methods of incorporating ancillary terrain data both show good advantage.

With the intensive environmental data like DEM and remotely sensed data from satellites and ground-based systems become increasingly available, they are likely to confer benefit in the context of general environmental management where sampling to record the variable and limits the accuracy of predictions. However, up to now there is no single best method for all variables. The coregionalization and the relations between the deterministic components of the variation should still be examined carefully before deciding on the most appropriate method of prediction.

ACKNOWLEDGEMENTS

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AGRICULTURAL CROSS LANGUAGES INFORMATION RETRIEVAL SCHEMA BASED ON MUTI-THESAURUS MAPPING

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Abstract: Based on the rapid development of Chinese agricultures, many English users are interesting on the Chinese agricultural information, and many Chinese users are interesting on English agricultural information too. This paper is a schema to design an agricultural cross languages engine, the core technology is the mapping between Chinese and English agricultural thesauri. The paper introduces the all rules of thesauri mapping, and give exact examples for these rules. With the mapping information, authors design a cross languages engine. English users can get Chinese agricultural information from web data by English descriptors; Chinese users can get English agricultural information from web data by Chinese descriptors

Keywords: cross languages search engine, mapping, thesaurus

1. INTRODUCTION

1.1 Background

Thesauri were born in 1950s, and, since then, they have been broadly used in different domains, both by humans and machines. In particular, they were

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successfully used in information retrieval (Chang Chun, 2002). A thesaurus can be considered as a system for representing domain knowledge: it has some basic relationships between concepts/terms, and it is managed by information and domain specialists. From the '90s of 20 century, Internet has been used broadly: users can find enough information in Internet searching by keywords. Despite of that, sometimes it is possible to get so many results that it is difficult to select what is need. In order to avoid these problems, some information specilists research thesauri and ontology to resolve these problems (Chang Chun et al., 2004; Qin Jian, 2001).

The FAO developed a multilingual agricultural thesaurus, AGROVOC, it is a multilingual, structured and controlled vocabulary designed to cover the terminology of all subject fields in agriculture, forestry, fisheries, food and related domains (e.g. environment). AGROVOC is online, users can browse and down it on web. It has 17 languages now, include 5 FAO official languages, they are Arabic, Chinese, English, French, Spanish; each language has about 30 thousand terms(Agricultural Information Management Standards, 2008). the Chinese Academy of Agricultural Sciences (CAAS) has developed the Chinese Agricultural Thesaurus (CAT) in Chinese with English translation (Information Institute of Ministry of Agriculture, 1994). As both of the thesauri concerns the agricultural domain, and each of them has its own structure and particularities, the leading organizations decided to realize a mapping of the domain knowledge between these two thesauri; the resulting inter-thesaurus could then be used to develop applications from which both English and Chinese users can benefit. For example, we can develop a search engine to search databases containing different languages. Based on this ideas, FAO and CAAS organized a mapping project from CAT to AGROVOC at the end of 2005(Chang Chun, 2006; Chang Chun 2007).

1.2 Work methods

The mapping schema was based on the SKOS rules (Miles, et al ., 2004), which has been revised and adapted based on FAO and CAAS needs (e.g. the *inexactMatch* rule was used but not the *majorMatch* and *minorMatch*). All major rules and logical operators, such as *exactMatch*, *broadMatch*, *narrowMatch*, AND, OR, NOT, were included in the mapping mechanism. Based on our initial analysis, we also supposed that some CAT concepts/terms would not have a mapping in AGROVOC.

Part of the preparative work, was the conversion of the CAT Foxpro database to Microsoft Access, both thesauri have been represented with the Ontology Web Language (OWL). In order to improve performances and allow distributed work, CAT concepts, have been split into categories. Each

of the OWL files containing separate concepts grouped by category would have been given to a specific expert for performing the mapping.

The tool used to realize the mapping is Protégé: all CAT OWL files would have been processed separately. In a second phase, all the mapping files would have been incorporate in a unique document.

2. USE PROTÉGÉ TO EXPRESS ALL RELATION RULES

OWL can express the mapping relations well, we use OWL to keep the mapping relation information.

2.1 The exactmatch relation

ExactMatch is one of the main relation of the mapping project. It is recorded as ‘equivalentClass’ in OWL. Such as ‘禾谷类作物’ (English translation ‘Cereal crop’, Chinese termcode 17147) exact match with ‘Cereal crops’ (Chinese translation “禾谷类作物”, English termcode 25512), we got the OWL document with Protégé, here is a part of the OWL document.

```
<rdf:Description rdf:about="http://www.caas.net.cn/2005/cat#c_17147_禾谷类作物_Cerealcrop">
  <owl:equivalentClass>
    <rdf:Description rdf:about="http://www.fao.org/aos/agrovoc/2005#c_25512_Cerealcrops_禾谷类作物">
      <owl:equivalentClass rdf:resource="http://www.caas.net.cn/2005/cat#c_17147_禾谷类作物_Cerealcrop"/>
    </rdf:Description>
  </owl:equivalentClass>
</rdf:Description>
```

2.2 The broadmatch relation

BroadMatch is another main relation of the mapping project. It is recorded as ‘subClassOf’ in OWL. Such as ‘普及教育’ (Universal education, Chinese termcode 35234) broad match with ‘Education’ (Chinese translation “教育”, English termcode 2488), the OWL document is as follow.

```
<rdf:Description rdf:about="http://www.caas.net.cn/2005/cat#c_35234_普及教育_Universaleducation">
  <rdfs:subClassOf rdf:resource="http://www.fao.org/aos/agrovoc/2005#c_2488_Education_教育"/>
</rdf:Description>
```

2.3 The narrowmatch relation

NarrowMatch seldom happen in our mapping project. It is also recorded as ‘subClassOf’ in OWL. Only need do it on the reversal way. Such as ‘岛屿’ (Islands, Chinese termcode 8341) narrow match with ‘Atolls’ (Chinese translation “环礁”, English termcode 695), the OWL document is as follow.

```
<rdf:Description rdf:about="http://www.fao.org/aos/agrovoc/2005#c_695_Atolls_环礁">
  <rdfs:subClassOf rdf:resource="http://www.caas.net.cn/2005/cat#c_8341_岛屿_Islands"/>
</rdf:Description>
```

2.4 the AND relation

There are some AND relations in the mapping project. It is recorded as ‘intersectionOf’ in OWL. Such as ‘自动标引’ (English translation ‘Automatic indexing’, Chinese termcode 59683) exact match with the conception of ‘Indexing of information’ (Chinese translation “信息编目”, English termcode 11729) AND ‘Automation’ (Chinese translation “自动化”, English termcode 15855), the OWL document is as follow.

```
<rdf:Description rdf:about="http://www.caas.net.cn/2005/cat#c_59683_自动标引_Automaticindexing">
  <owl:equivalentClass>
    <owl:Class>
      <owl:intersectionOf rdf:parseType="Collection">
        <rdf:Description rdf:about="http://www.fao.org/aos/agrovoc/2005#c_11729_Indexingofinformation_信息编目"/>
        <rdf:Description rdf:about="http://www.fao.org/aos/agrovoc/2005#c_15855_Automation_自动化"/>
      </owl:intersectionOf>
    </owl:Class>
  </owl:equivalentClass>
</rdf:Description>
```

2.5 the OR relation

There are some OR relations in the mapping project. It is recorded as ‘unionOf’ in OWL. Such as ‘大麦’ (Barley, Chinese termcode 7536) exact match with the conception of ‘Barley’ (大麦, English termcode 823) OR ‘Hordeum vulgare’ (大麦植物, English termcode 3662), the OWL document is as follow.

```
<rdf:Description rdf:about="http://www.caas.net.cn/2005/cat#c_7536_大麦_Barley">
  <owl:equivalentClass>
    <owl:Class>
      <owl:unionOf rdf:parseType="Collection">
```

```
<rdf:Description rdf:about="http://www.fao.org/aos/agrovoc/2005#c_823_Barley_大麦"/>
<rdf:Description rdf:about="http://www.fao.org/aos/agrovoc/2005#c_3662_Hordeumvulgare_大麦植物"/>
</owl:unionOf>
</owl:Class>
</owl:equivalentClass>
</rdf:Description>
```

2.6 the NOT relation

There are some NOT relations in the mapping project. It is recorded as ‘complementOf’ in OWL. Such as ‘非传染性病害’ (English translation ‘Non-infectious diseases’, Chinese termcode 12114) exact match with the conception of ‘Plant diseases’ (Chinese translation “植物病害”, English termcode 5962) AND NOT ‘Infectious diseases’ (Chinese translation “侵染性病害”, English termcode 34024), the OWL document is as follow.

```
<rdf:Description rdf:about="http://www.caas.net.cn/2005/cat#c_12114_非传染性病害_Non-infectiousdiseases">
<owl:equivalentClass>
<owl:Class>
<owl:intersectionOf rdf:parseType="Collection">
<rdf:Description rdf:about="http://www.fao.org/aos/agrovoc/2005#c_5962_Plantdiseases_植物病害"/>
<owl:Class>
<owl:complementOf rdf:resource="http://www.fao.org/aos/agrovoc/2005#c_34024_Infectiousdiseases_侵染性病害"/>
</owl:Class>
</owl:intersectionOf>
</owl:Class>
</owl:equivalentClass>
</rdf:Description>
```

2.7 The comment of No Mapping relation

Some terms have no mapping relation with AGROVOC, we use the comment tool to express it. It is recorded as ‘comment’ in OWL. Such as ‘干扰’ (English translation ‘Interference’, Chinese termcode 13867) has no mapping relation terms in AGROVOC, the OWL document is as follow.

```
<rdf:Description rdf:about="http://www.caas.net.cn/2005/cat#c_13867_干扰_Interference">
<rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
>AGROVOC hasn't this concept</rdfs:comment>
</rdf:Description>
```

3. THE CHINESE-ENGLISH CROSS SEARCH ENGINE BASED ON MAPPING WORK

Based on the rapid development of Chinese agricultures, Chinese people have enough food for their life. How they resolve food problems for this 1.3 billion people, many English users are interesting on the Chinese agricultural information. As Chinese agricultural economy is becoming one part of world economy, many Chinese users are interesting on English agricultural information too. Based on the mapping project, we have gotten a design schema, it is an agricultural cross languages engine, and the core technology is the mapping between Chinese and English agricultural thesauri. With the mapping information, English users can get Chinese agricultural information from web data by English descriptors, Chinese users can get English agricultural information from web data by Chinese descriptors. The system lines are in the Fig. 1.

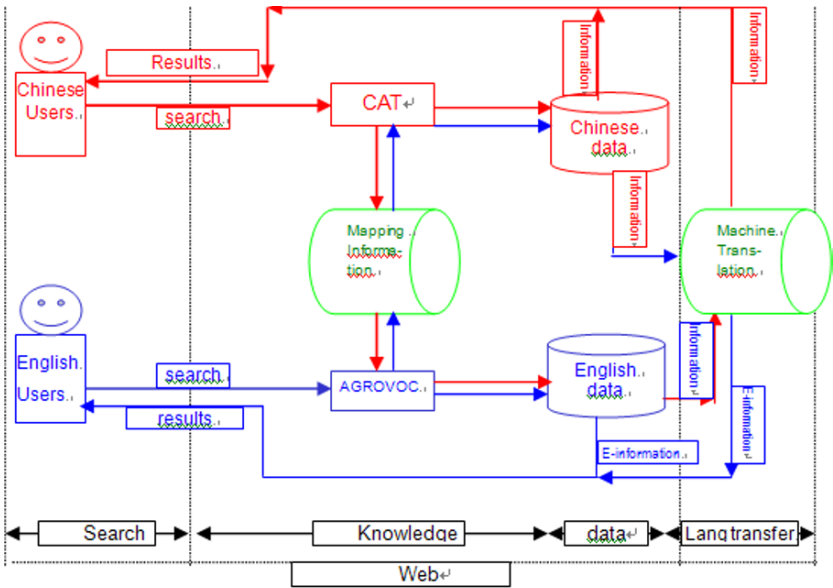


Fig. 1: Cross languages search engine architecture

We design to use machine translation system, as Chinese-English machine translation software can give enough translation information for users. Although there are some errors when users read the translation information, they can get more useful information. If users want to get native language information, the information organizations can give these kinds of service.

4. DISCUSSIONS

4.1 The development of data languages

The information of thesauri and mapping, can be keep with different data languages, human beings renew these languages continually. First we use RDF to keep these information, then we have OWL. Some years later, we will have other more new languages to repeat them. With the different languages, we have more chances to express new function. So there is a problem, it means we must develop tools to convert different languages documents, we need to keep original knowledge, or rebuilt these knowledge to new styles. The best method is to use conversion tool directly, as this research is quite new, normally we can't find standard tools.

4.2 The main problem of cross languages search engine

Thesauri are design to used by human and computer, indexers choose some appropriate concepts in thesauri to index documents, readers can find these documents with concepts, some time these information is keep in computers. For our cross language search engine, it is based on Internet, users normally don't know or no need to know thesauri, they more like to use natural languages, such as keywords, how these keywords can convert thesauri concepts? This is an important problem, thesauri can only to resolve some problems, we can give relationships artificially, but this is a huge work too, and seem no organizations can finish this work. For this problem, it is impossible to include all conversion information, we just try to make it useful to users, and this is the correct way to resolve the problem.

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QUANTIFY THE LANDSCAPE EFFECT OF RURAL REGION PLANNING NEAR METROPOLIS USING HIGH SPATIAL RESOLUTION REMOTE SENSING-CASE STUDY IN GAOLIYING TOWN IN BEIJING

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Abstract: The urban fringe which can be seen as a special form of regional ecosystems with a spatial structure gradually from urban to rural areas of transition, has strong heterogeneity and is typical of ecologically sensitive areas. The expansion of city caused wide attention to the landscape effect of the changes. With the help of GIS, we got landscape pattern changes before and after town planning of Gaoliying town in Beijing by using high resolution image and large-scale map. The results showed that landscape shape index, contagion index and Simpson evenness index increased while landscape diversity index reduced. The pattern of reasonable land use would improve and landscape pattern come to perfect. The intensity index of human disturbance increased. Comparing three increase modes of town development, the landscape pattern change of Gaoliying town is peripheral increase mode.

Keywords: edge of city; land use; landscape pattern index; land plan; landscape effect

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1. INTRODUCTION

Urban fringe is a certain stage of urban development when the social, economic functions and impacts spreading from the core areas to the surrounding region. It was formed between urban and rural areas and its features, structure and function exhibit between urban and rural region. The interaction and integration of social, economic, environmental, and other elements between the villages, towns and city existed in these special zones. From formation and development process of urban fringe, it is a result of urban centralization and extension. It can be seen as a specific phase of a typical form of urbanization (Mao and Liu, 2005). The edge zone of Beijing covers most of the plain areas where arable land is the major land use. It is also the frontal areas undergoing urbanization process (Li, 2006). Small towns' development is the center in the development of edge zone of Beijing and play important role in the process of urbanization and sustainable urban development (Cui, 2001). It is practical to study The development of cities will inevitably lead to land use and land cover changes (Bao and Men, 2003). At present, the ecological and environmental effect of land use/land cover changes and land planning causes increasing attention. At landscape scale, most studies focused on quantifying the structure and characteristics of regional land-use changes (Lu et al., 2001).

Although in China, many researchers have carried out a great deal of studies on this topic, most studies focused on the large-scale urban or representative land use change (Li, 2004). Also, these studies mainly focused on the comparison between historical and current situation. Modeling method was used to elucidate the landscape effect of land use change which often results in large errors. The scope of small-scale land-use change and landscape effects of land planning was little touched. At town scale, landscape effect study of land planning in the urban edge area has not yet been involved.

This paper takes Gaoliying town in Shunyi district in Beijing as an example to study the landscape effect. We used high spatial resolution SPOT image, GIS and landscape software FRAGSTAT to quantify the landscape pattern before and after the landscape planning.

2. THE OVERVIEW OF STUDY AREA

Gaoliying town is located in the northeast suburbs of Beijing in Shunyi Distric covering an area of 54 square kilometers. It is one of the 27 key planning towns in Beijing and was identified as the central town in Shunyi District. The town is also an important agricultural and industrial base. There are 24 administrative villages with 230,000 resident populations. Transport

facility and transportation network was developed with vantage location conditions. The climate in Gaoliying is warm temperate and semi-arid sub-continental monsoon with ample sunshine throughout the year and four distinct seasons. At present, the landscape is mainly agricultural ecosystem and lies in the transitional zone of urban and rural areas.

3. METHODS

3.1 Data acquisition

Current land use type map was derived from SPOT image in 2006. RS and GIS software was used to classify the landscape. The 1:30000 scale topographic maps were used for geometric rectification. Then image-to-image registration was conducted between the image and 1:30000 map using the nearest neighbor resampling algorithm. Root mean square (RMS) errors of each registration were maintained below 0.5 pixels (<1m). Also a field survey was conducted to rectify the map. The land plan map was digitalized from the papyry land plan map (1:30000). In order to compare, a consistent system of classification were used.

3.2 Methods

Landscape consists different size of patches and the spatial distribution of patches is called as landscape pattern (Fu et al., 2001). Landscape pattern is the result of long-term natural or anthropic effect, also the landscape pattern can directly affect the process.

Landscape indexes can highly concentrate the information of landscape patterns. They can reflect landscape composition and spatial configuration by simple quantitative indicators (Wu, 2007).

Based on the regional landscape features, We selected Patch Density, Fractal Dimension, Landscape Shape Index, Contagion Index, Shannon Diversity Index, Simpson Evenness index, Human disturbance index to characterize the landscape effect of planning. With the support of Arcinfo, land use and land planning vector map were converted into landscape grid map (grid resolution of 2m). The landscape indexes were calculated by FRAGSTAT program (Deng et al., 2005; Yang et al., 2005).

4. RESULTS

4.1 Land use change before and after town planning

In this paper, a uniform classification of landscape was used to avoid the error from different classification (Yan, 2004). Landscape in Gaoliying town was divided into farmland, woodland, water, constructed land (including public facilities, industrial sites), residential area, town land, road, green land and other types (Figure 1). Land use change before and after town planning was listed in Table1.

The proportion of a landscape type of the entire landscape area represents the contributing rate of each landscape type (He et al., 2005). From Table 2, the landscape area was farmland > woodland > constructed land > residential area > garden land > water body > road> waste land > town land > green land. After land planning, landscape area will show farmland > green land > road > constructed land > town land > water body > residential area > garden land. Obviously, the farm land are the main land use type before and after land planning which accounts for 35.52% at present and for 59.78% after planning. This result showed that agricultural landscape is the dominant landscape type in Gaoliying town. Also, the intensive land planning will bring out more farmland. Woodland, constructed land, residential area, garden land, and water body will reduce after planning while the Town land, Road and Green land will increase.

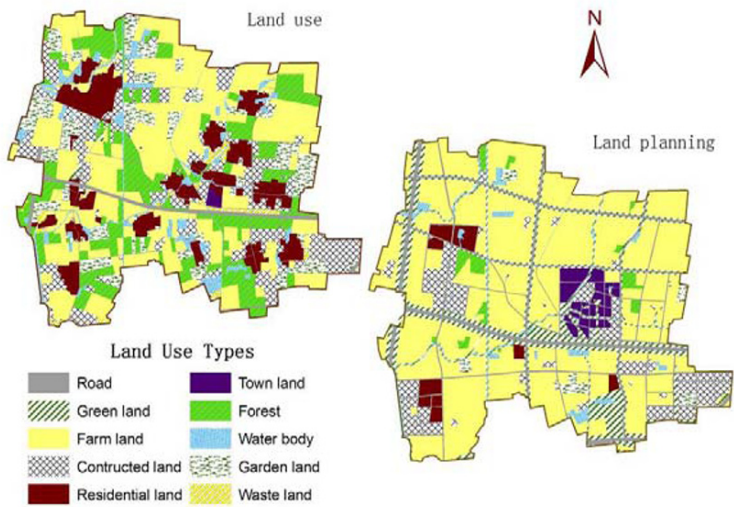


Fig. 1: Land use and land plan Map in Gaoliying town

Table 1 Changes of land use before and after town planning in Gaoliying

Landscape type	Present		Land planning		Area changed
	Area (hm ²)	Ratio(%)	Area (hm ²)	Ratio(%)	Area (hm ²)
Road	180.01	3.36	505.99	9.44	325.98
Green land	6.87	0.13	631.19	11.78	624.32
Farmland	1904.06	35.52	3204.47	59.78	1300.41
Constructed land	765.72	14.29	451.19	8.42	-314.53
Residential area	617.18	11.51	131.42	2.45	-485.76
Town land	15.84	0.3	134.8	2.51	118.96
Woodland	931.72	17.38	93.94	1.75	-837.78
Water body	280.84	5.24	134.74	2.51	-146.1
Garden land	562.23	10.49	72.27	1.35	-489.96
Waste land	95.53	1.78	—	—	-95.53
Sum	5360	100	5360.01	100	0.01

The proportion of town land can scale the urbanization level (Yuan et al., 2003). Obviously, the urbanization level of Gaoliying town is very low at present which the town land proportion is only 0.30%. Also, the town infrastructure of roads and green land account for a smaller proportion with 3.36% and 0.13% respectively. After land planning, the urbanization level will increase to 2.51%, waste land will be fully developed and the roads and green land increase to 9.44 % and 11.78%.

4.2 Land-use transfer matrix analysis

Using GIS spatial analysis, land use and land plan vector map were overlaid for statistical analysis. The transfer probability matrix before and after land use planning was shown in Table 2.

Table 2 Transfer probability matrix between different land use before and after town planning

Landscape type	Before planning									
	Road	Green land	Farm land	Constructed land	Residential area	Town land	Wood land	Water body	Garden land	Waste land
Road	77.0%	5.5%	7.2%	9.2%	7.5%	13.3%	5.5%	5.8%	6.3%	10.1%
Green land	8.1%	3.3%	9.7%	10.2%	7.1%	30.6%	19.0%	12.1%	8.6%	42.2%
Farmland	11.3%	33.9%	72.8%	38.9%	57.4%	0.0%	65.6%	36.2%	72.2%	29.2%
Constructed land	2.0%	57.4%	6.5%	33.1%	2.1%	0.0%	2.7%	2.0%	3.2%	5.2%
Residential area	0.1%	0.0%	1.3%	2.6%	13.6%	0.0%	0.0%	1.1%	0.0%	0.0%
Town land	0.3%	0.0%	1.1%	2.2%	10.0%	55.1%	0.4%	1.6%	1.3%	11.1%
Woodland	0.3%	0.0%	0.6%	2.0%	0.0%	0.0%	6.2%	2.4%	0.2%	0.0%
Water body	0.7%	0.0%	0.3%	0.8%	1.4%	1.1%	0.6%	36.9%	0.2%	2.2%
Garden land	0.2%	0.0%	0.5%	0.9%	0.9%	0.0%	0.0%	1.7%	8.1%	0.0%

From table 3, the transfer of different land uses were as follows: 1) the increase of road area is mainly from the town land, waste land, constructed land and the conversion ratio was 13.3%, 10.1%, 9.2%; 2) The decrease of garden land, woodland, residential area, constructed land contribute to the increase of farmland and the conversion rate was 72.2%, 65.6%, 57.4%, 38.9%, 36.2%; 3) the increase of town land comes mainly from waste land and residential area and of which 11.1% of waste land and 10.0% residential area have been developed for town land; 4) the increase of green land is mainly from the waste land and town land and the conversion rate is 42.2% and 30.6%. 5) Wasteland will be fully transferred into other landscape types except woodland and garden land.

4.3 Quantitative analysis of landscape pattern changes

4.3.1 Patch level

We selected patch number, patch density and fractal dimension to analyze the landscape change after landscape plan (Table 3).

Table 3 Patch number, patch density and fractal dimension changes before and after planning

Landscape types	Patch number		Patch density		Fractal dimension	
	Present	Planning	Present	Planning	Present	Planning
Road	51	34	4.367	1.704	1.4565	1.4283
Green land	2	180	0.038	3.838	1.1311	1.4299
Farmland	90	121	0.750	0.917	1.2741	1.2886
Constructed land	165	95	1.443	0.805	1.3206	1.2966
Residential area	41	10	0.375	0.112	1.2517	1.1782
Town land	1	24	0.019	0.187	1.0147	1.2248
Woodland	85	19	0.862	0.206	1.2925	1.2263
Water body	71	53	2.493	2.378	1.3804	1.3883
Garden land	44	10	0.656	0.131	1.2521	1.1943
Waste land	28		0.694	—	1.3166	—

As shown in table 4, the road have more patch numbers and the largest patch density which suggest the high fragmentation and scattered distribution. After planning, the road patch number and patch density decreased which suggest the concentrated road distribution and developed network. And the road network will strengthen the link between villages. The patch number of farmland, town land and green land increase which suggest these land types were greatly impacted by human activities.

For the fractal dimension, the town land is close to 1.0 and most fractal dimension decreased after planning. It is obvious that the shape of town land

is simple and regular. Also, the road, constructed land, residential area, wood land, garden land, waste land would be modified by human interference and tend to shape simple.

4.3.2 Landscape scale

At landscape scale, we selected landscape shape index, contagion index, Shannon diversity index, Simpson evenness index, human disturbance index to analyze the overall landscape pattern changes (Table 4).

Table 4. Changes of landscape pattern index before and after planning

Landscape index	landscape shape index	Contagion index	Shannon diversity index	Simpson evenness index	human disturbance index
Present	14.3118	48.8020	1.8027	1.1111	3.0766
Planning	16.4249	56.1687	1.3962	1.1250	5.2338

Table 5 showed that the landscape shape index, contagion index increased after land planning. The results suggest that a few large patches will be dominant in the landscape with high connectivity between the same types of patches. The phenomenon is mainly due to the village centralization policy in the planning. The centralization will combine a number of small near villages with similar natural conditions, customs and habits into a centre village. This will result in the decrease of patches of rural settlements. Also, with the decrease of woodland, water body, garden land, constructed land patch number and the increase of farmland, the connectivity of adjacent patches will increase.

The reason for the decrease of Shannon diversity index is mainly due to the great variation of landscape types after planning. The farm land account for more than 59% and the wastelands were all converted into other lands. After planning the Simpson evenness index increased which indicated that landscape types will distribute more evenly and the fragmentation level decrease.

The human disturbance index increased and this is mainly because the farmland increased greatly. Also the woodland and water body with less human disturbance will decrease after planning.

5. CONCLUSIONS AND DISCUSSIONS

The study takes Gaoliying town as an example to analyze the landscape effect of land planning. Evidently land use will take on great changes with different land use conversion. At patch and landscape scale, further

quantitative analysis was conducted to get a whole condition of land use change. After planning, landscape diversity decreased and the landscape shape index, contagion index and evenness index increased.

The results showed human disturbance and the urbanization level will increase, while at the same time the farmland will also increase with the intensive agriculture development. The planning is a rational approach for farm land protection and urbanization. In Beijing, the development pattern is a suitable mode under the quick urbanization area. From the study, we can derive that Gaoliying town belong to merging growth pattern, that is, integrating farmlands and constructed land to meet the relative concentration of urban development and management.

In the process of urbanization, urban fringe should be frontier for the ecological protection. Reasonable landscape pattern should be established for the land use planning. At the town scale, it is obviously that high resolution image can play important role in the land use management.

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EFFECTS OF LAND USE ON SOIL QUALITY ON THE LOESS PLATEAU IN NORTH-WEST SHANXI PROVINCE

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Abstract: Northwest Shanxi is located at the eastern border of the Loess Plateau. In order to guard against wind, to conserve water and soil, to fix sand, a large area of Caragana microphylla was planted in the hilly loess plateau in the north-west Shanxi province during the 1960s. To investigate how these measures affected soil properties and ultimately soil quality, a case study was conducted in Wuzhai (North-west Shanxi Province). Soil samples were collected from adjacent Caragana microphylla land, farm land, poplar forests, fallow land and mixed plantations of Caragana microphylla and poplar. Initially, soil properties under the five land-uses were studied separately. Then an evaluation indicator system was developed according to the principle of evaluation indicator selection. Subsequently, the method of multivariate analysis was used to carry through a complete scientific evaluation. Results showed a significant influence of land-use on soil properties. The value of SQI was the highest under the mixed plantation and, compared with the mixed plantation, the SQI of farmland decreased greatly. The SQI of fallow land was the lowest, but considering the soil nutrient content, land fallowing improved soil fertility to some extent. It was further shown that growing Caragana microphylla and mixed polar and Caragana microphylla plantation was the most sustainable ways of developing the loess plateau.

Keywords: Loess Plateau, Land use, Soil quality, Caragana microphylla

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1. INTRODUCTION

The loess plateau is the energy and heavy chemical industry base and ecological barrier of eastern region and the frontier of ecological barriers. At present, the loss plateau is one of the areas of China where ecological degradation is most serious and the sustainable development ability is the lowest. The grave loss of soil and water, not only threaten the sustainable development of the loess plateau, but also the surrounding area even the whole nation directly.

Northwest Shanxi is located on the eastern border of the loess plateau. In order to guard against wind, to conserve water and soil, to fix sand and to develop animal husbandry, a large area of *Caragana microphylla* was planted in the hilly loess plateau in the north-west Shanxi province during the 1960s. *Caragana microphylla* has a developed rootstructure, is very hardy, and has considerable ability to conserve water and soil. However, to date, it is unknown whether these measures have been effective.

The aim of this research is to choose a representative site in north-west Shanxi Province, study soil properties and soil quality under different land uses in this area, and evaluate the existing ecology renewal measures.

2. MATERIALS AND METHODS

2.1 Study sites

The experiment was conducted in Wuzhai County (38°44'~39°17'N and 111°28'~112°E), north-western Shanxi Province, in northern China. The county has a semi-arid climate. The average yearly temperature is 4.1°C—5.5°C, while the mean annual rainfall is 400mm. The altitude lies between 1200m and 1400m. the soil is loam and the soil fertility is regarded as poor (Liu and Zhang, 1992).

2.2 Soil sampling and analysis

From April to November 2006, soil samples were collected from five land use types every month. Five adjacent land-uses with the same slope, having similar terrain factors, and used continuously for 30 years were selected: (1) farmland (buck wheat), (2) *Caragana microphylla*, (3) poplar, (4) mixed plantation of *Caragana microphylla* and poplar, (5) fallow land (fallowed for 3 years). Three typical sites were selected in each land type. All of the sites were located by GPS and flagged separately. At each site, three soil samples

at each depth, 0-20 cm depth and 20-40 cm depth, were collected within a 100 cm radius.

Each sample weighed about 1 kg and samples from the same depth and the same site were bulked for analysis. Soil samples were analyzed for organic matters (OM), total nitrogen (TN), available P (AP), available K (AK), total K (TK), and total P (TP), soil bulk density, pH and soil enzyme activity. Bulk density was determined by the core method. Soil pH was determined in 1:2.5 soil slurry, using a combination glass electrode. Soil OM was analyzed using the rapid dichromate oxidation techniques (Tiessen and Moir, 1993), TN was measured using the Kjeldahl technique (McGill and Figueiredo, 1993), and AP was extracted using the Olsen method (Olsen and Dean, 1965). AK was extracted with 1N ammonium acetate, adjusted to pH 7 (Simard, 1993), TP and TK were determined in a nitric-perchloric digestion extract, P by the method of Murphy and Riley (1962) and K by flame photometry.

2.3 Evaluation method

An evaluation indicator system, including physical indicators, chemical indicators and biological indicators was developed according to the principle of evaluation indicator selection. Following this, multivariate statistical analysis was used to carry through a complete scientific evaluation: according to membership function, realized the transaction of original data to the same dimension; as well as utilizing principle component analyzing solved how to determine the distribution of weightiness about every evaluated indicator.

We conducted one-way analyses of variance (ANOVAS) using SPSS software, with land use class as the main effect. The LSD procedure was used to separate the means of the soil properties at $p \leq 0.05$. Principal component analysis was used to determine the distribution of weightiness about every evaluated indicator.

3. RESULTS AND DISCUSSION

3.1 Effects of land use on soil physical, chemical and biological properties

Soil under Caragana microphylla had the lowest bulk density, liquid percent, solid percent and the highest gas percent, and compared with other

land uses, the difference was significant (Table 1). Soil of fallow land had the highest bulk density, 1.51 g/cm³ and the lowest gas percent.

Tab.1 Effects of land use types on soil bulk density (0~20cm)

Land use	Sampling depth (cm)	Bulk density (g/cm ³)	Liquid percent (%)	Gas percent (%)	Solid percent (%)
Fallow land	0~20	1.51 ^a	16.2 ^a	22.37 ^d	61.43 ^a
Farm land	0~20	1.33 ^{bc}	13.5 ^b	35.82 ^b	50.73 ^c
<i>Caragana microphylla</i>	0~20	1.16 ^d	11.7 ^d	39.91 ^a	48.39 ^c
Mixed plantation of poplar and <i>Caragana microphylla</i>	0~20	1.29 ^c	12.4 ^c	37.76 ^b	49.89 ^c
poplar	0~20	1.37 ^b	13.1 ^b	31.95 ^c	54.95 ^b

Different letters above data represent statistically significant difference at $p < 0.05$.

The root system of *Caragana microphylla* belongs to the axis-tiller type and has a strong penetration. During the root growth process, the soil is loosened leading to a decrease of bulk density and solid percent and an increase of gas percent (Niu *et al.*, 2003). Consequently, soil density under *Caragana microphylla* was the lowest and, also because of the presence of roots of *Caragana microphylla*, the soil bulk density of the mixed plantation of *Caragana microphylla* and poplar was lower than that of poplar forest and this difference was significant. Due to human activity and animal tracking, fallow land had the highest soil bulk density.

Soil under the mixed plantation had the highest soil organic matters and total nitrogen (Table 2), most likely as a result of the abundant litter on the surface soil of the mixed plantation and the obvious humification of litter (Peng *et al.*, 1996). Soil OM and TN under *Caragana microphylla* and poplar were lower than that under the mixed plantation, but higher than that under fallow land and farmland (Table 2). Soil under farmland had the lowest OM and TN (Table 2). This was because there were less residues accumulating on the surface of farmland, coupled with the impact of cultivation which enabled the rapid decomposition of the organic matter and the release of nitrogen. This nitrogen was available to, on one hand be absorbed and assimilated by the crops, but on the other hand be a major source of nitrate leaching (Peng *et al.*, 1996). Higher soil OM content in shrub land compared with that in arbor land was also reported in a small catchment of the Loess Plateau (Gong *et al.*, 2004).

The trend of AK content between the several land use types was similar to the trend of organic matter. The soil under poplar had the lowest AP content (Table 2). The AP under *Caragana microphylla* and the mixed plantation was higher than that under poplar, but lower than that under farmland (Table 2). The use of P fertilizer may account for the highest AP content of soil in farmland. Because of the huge plant biomass, high absorption of soil nutrients and the obvious assimilation of available nutrients, AP and AK content under *Caragana microphylla* were lower relatively (Niu *et al.*, 2003). Qiu *et al.* (2004), studying soil nutrients in different land uses in a small

catchment of the Loess Plateau, reported soil in shrub land had the lowest AP content.

Tab.2 Effects of land use types on selected chemical properties(0~20cm)

Land use		Organic matter (g/kg)	Total-N (g/kg)	Total-P (mg/kg)	Total-K (mg/kg)	Olsen-P (mg/kg)	Available K (mg/kg)	pH
Fallow land	maximum	6.378	0.848	536.43	2181.61	1.8689	72.00	8.59
	minimum	5.918	0.478	460.44	1562.81	0.8379	59.50	8.51
	mean	6.187	0.597	496.64	1815.49	1.5307	68.25	8.57
	C.V	0.031	0.273	0.060	0.148	0.307	0.086	0.004
farmland	maximum	6.931	0.677	617.02	1935.40	4.1793	70.75	8.68
	minimum	5.353	0.469	472.94	1506.35	1.9116	50.25	8.35
	mean	5.889	0.581	509.09	1735.18	2.7699	62.90	8.49
	C.V	0.113	0.172	0.119	0.093	0.444	0.121	0.016
Caragana microphylla	maximum	7.173	0.820	564.31	3572.06	1.9688	132.50	8.57
	minimum	6.052	0.489	349.58	2426.31	1.0049	70.50	8.53
	mean	6.450	0.624	461.72	3086.92	1.2644	97.80	8.55
	C.V	0.072	0.196	0.189	0.152	0.372	0.246	0.002
Mixed plantation of poplar and Caragana microphylla	maximum	9.061	0.149	502.52	3139.83	1.2197	172.50	8.60
	minimum	7.072	0.520	388.35	1470.87	0.7667	77.00	8.49
	mean	7.973	0.755	439.28	2222.50	1.0129	130.70	8.55
	C.V	0.122	0.337	0.115	0.269	0.184	0.262	0.005
poplar	maximum	7.755	0.831	519.36	2664.61	0.8907	125.75	8.64
	minimum	4.425	0.464	393.29	1382.40	0.3835	87.00	8.49
	mean	6.378	0.611	429.36	2253.40	0.6247	107.15	8.57
	C.V	0.237	0.264	0.123	0.222	0.365	0.149	0.008

Catalase and alkaline phosphatase activity in the upper soil layer were significantly higher than that in the lower layer (Table 3). In contrast with the lower layer, the surface soil can more easily exchange matter and energy with atmosphere and the organic matter entering soil gathers first at the surface. Therefore, in the upper layer the nutrient conditions are better, activity of soil microbes is blooming and the enzyme activity is higher (An et al., 2004).

Tab.3 Effects of land use types on soil enzyme activity

Land use	Catalase 0.1NKMnO ₄ ml/100g.37°C.d ⁻¹		Alkaline phosphatase mg phenol/100g.37°C.d ⁻¹	
	0~20cm	20~40cm	0~20cm	20~40cm
Fallow land	222.1 ^b	143.5 ^c	1214.8 ^{bc}	918.3 ^b
Farm land	288.4 ^a	203.2 ^b	1185.1 ^c	919.6 ^b
Caragana microphylla	267.3 ^a	214.3 ^b	1458.4 ^a	902.6 ^c
Mixed plantation of poplar and Caragana microphylla	277.0 ^a	255.2 ^a	1250.2 ^b	948.5 ^a
poplar	270.5 ^a	242.9 ^a	1227.3 ^b	924.7 ^b

Different letters above data represent statistically significant difference at $p < 0.05$.

The top 20cm soil under *Caragana microphylla* had the highest soil alkaline phosphatase activity and there were significant differences between soil under *Caragana microphylla* and that under several other land use types (Table 3). The impact of *Caragana microphylla* roots and the decomposition and mineralization of litter improve soil physical condition and increase soil organic matter content. Good soil physical conditions and the high soil organic matter content induce an increase of diversity and number of soil microbes (Niu et al., 2003). This would have accounted for the higher alkaline phosphatase activity under *Caragana microphylla* and the mixed

plantation. There were no significant differences of catalase activity among the five land use types, but the catalase activity of fallow land was the lowest (Table 3).

3.2 Calculation of soil quality

We mainly considered soil fertility quality when the evaluation indicators were selected. The evaluated indicators were: x_1 —OM、 x_2 —TN、 x_3 —TP、 x_4 —TK、 x_5 —AP、 x_6 —AK、 x_7 —pH、 x_8 —Bulk density、 x_9 —total porosity、 x_{10} —alkaline phosphatase、 x_{11} —catalase.

3.2.1 Membership functions for different evaluation indicators

There is no clear extension, nor uniform dimension among different evaluation indicators, so the values measured can not be used in soil quality evaluation directly. We should apply normalized transaction. First of all, we must select membership functions for the different evaluation indicators.

(a) Ascending half trapezoidal membership function.

Within a certain range, some indicators are positively correlated with soil quality (such as soil fertility status, soil health, etc), and there is little influence on soil quality whether the indicator is under the lower limit or above the upper limit. The membership function of these indicators can be approximated to the distribution of an ascending half trapezoid (Fig. 1). Its membership function model is as follows:

$$\mu(x)=\begin{cases} 1 & (x\geq x_0) \\ x/x_0 & (x<x_0) \end{cases}$$

(1)

where x is the actual value of evaluated indicators, x_0 the upper limit and $\mu(x)$ is the membership function of x .

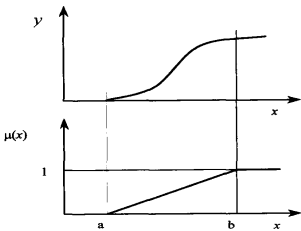


Fig.1 Distribution of “S” curve and trapezoid ascending half trapezoid

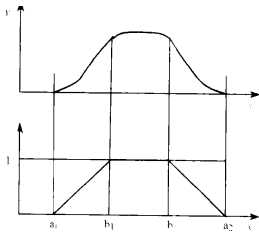


Fig.2 Distribution of parabola and trapezoid

(b) Triangular membership function

There is an optimum range when soil pH and bulk density influence the soil function. Within this range, the soil function is optimal. Over the range,

the bigger the deviation, the worse is the soil function. These indicators can be considered as a trapezoidal distribution (Fig.2). To simplify, we replaced optimum range with an optimum value; here the trapezoidal function is simplified to a triangular function (Fig. 3).

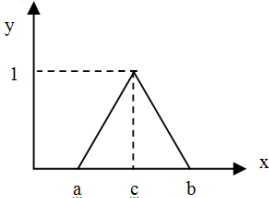


Fig. 3 Distribution of triangle

$$\mu (x) = \begin{cases} 0 & (x \leq a \text{ 或 } x \geq b) \\ \frac{x-a}{c-a} & (a < x < c) \\ \frac{b-x}{b-c} & (c < x < b) \\ 1 & (x = c) \end{cases}$$

(2)

Where x is the actual value of the evaluation indicator, b is the upper limit value, a is the lower limit value, c is the optimum value of the evaluation indicator and $\mu (x)$ is the membership function of x .

Secondly, we ascertained the limit value of the indicators according to the actual value measured in this study area (Table 4).

Then, according to the limit value of the evaluation indicators, the membership values were calculated (Table 5, Table 6).

Tab.4 Limit values of evaluated indicators

Indicator	Upper limit		Medium limit		Lower limit	
	value	membership	value	membership	value	membership
Bulk density/g/cm ³	1.8	0	1.1	1	0.9	0
Total porosity /%	51.61	1	—	—	0	0
pH	9.5	0	8.5	1	7	0
AP/mg/kg	2.7699	1	—	—	0	0
AK/mg/kg	130.7	1	—	—	0	0
TN/g·kg ⁻¹	0.755	1	—	—	0	0
TP/mg/kg	509.09	1	—	—	0	0
TK/mg/kg	3086.92	1	—	—	0	0
OM/g·kg ⁻¹	7.973	1	—	—	0	0
Alkaline phosphatase /mg phenol /100g.37℃.d ⁻¹	1458.4	1	—	—	0	0
Catalase/0.1NKMnO ₄ ml/100 g.37℃. d ⁻¹	288.4	1	—	—	0	0

Tab.5 Membership function values of evaluated indicators

Land use	OM	TN	TP	TK	AP	AK
Fallow land	0.776	0.791	0.976	0.588	0.553	0.522
farmland	0.739	0.770	1.000	0.562	1.000	0.481
Caragana microphylla	0.809	0.826	0.907	1.000	0.456	0.748
Mixed plantation of poplar and Caragana microphylla	1.000	1.000	0.863	0.720	0.366	1.000
poplar	0.800	0.809	0.843	0.730	0.226	0.820

Tab.6 Membership function values of evaluated indicators

Land use	pH	Bulk density	Total porosity	Alkaline phosphatase	catalase
Fallow land	0.930	0.414	0.747	0.833	0.770
farmland	1.000	0.671	0.955	0.813	1.000
Caragana microphylla	0.950	0.914	1.000	1.000	0.927
Mixed plantation of poplar and Caragana microphylla	0.950	0.729	0.971	0.857	0.960
poplar	0.930	0.614	0.873	0.842	0.938

3.2.2 Determining the weightiness of evaluated indicators

In this paper we utilize principal component analysis to determine the weightiness of evaluated indicators.If the Eigen values of the principal component is greater than 1 and the cumulative contribution rate is 85% or greater than 85%, the principal component can be extracted.

Tab.7 Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.233	47.576	47.576	5.233	47.576	47.576
2	3.190	29.003	76.580	3.190	29.003	76.580
3	1.910	17.367	93.947	1.910	17.367	93.947
4	.666	6.053	100.000			
5	8.536E-16	7.760E-15	100.000			
6	4.504E-16	4.095E-15	100.000			
7	1.712E-16	1.557E-15	100.000			
8	-1.010E-16	-9.183E-16	100.000			
9	-2.283E-16	-2.076E-15	100.000			
10	-3.050E-16	-2.773E-15	100.000			
11	-6.928E-16	-6.298E-15	100.000			

Extraction Method: Principal Component Analysis.

Tab.8 Component Matrix

	Component		
	1	2	3
OM x1	0.762	-0.209	0.514
TN x2	0.751	-0.150	0.534
TP x3	-0.850	0.347	-7.009E-02
TK x4	0.747	0.178	-0.639
AP x5	-0.697	0.664	0.158
AK x6	0.935	-0.221	0.266
pH x7	-0.307	0.895	0.322
Bulk density x8	0.699	0.669	-0.252
Total porosity x9	0.618	0.783	7.569E-02
Alkaline phosphatase x10	0.587	0.253	-0.730
catalase x11	0.374	0.747	0.382

Extraction Method: Principal Component Analysis.

In Table 7, the cumulative contribution rate of the first three components is 93.947%. From this we can also see that the three components can almost

reflect the information of all of the indicators. We can thus replace the 11 components with the first three components.

Dividing the data in Table 8 by the square root of eigenvalues, we can get the corresponding coefficient of the indicators in the first three principal components. The three principal components are as follows:

$$F1 = 0.333x_1 + 0.328x_2 - 0.372x_3 + 0.327x_4 - 0.305x_5 + 0.409x_6 - 0.134x_7 + 0.306x_8 + 0.270x_9 + 0.257x_{10} + 0.163x_{11} \quad (3)$$

$$F2 = -0.117x_1 - 0.084x_2 + 0.194x_3 + 0.100x_4 + 0.372x_5 - 0.124x_6 + 0.501x_7 + 0.375x_8 + 0.438x_9 + 0.142x_{10} + 0.418x_{11} \quad (4)$$

$$F3 = 0.372x_1 + 0.386x_2 - 0.051x_3 - 0.462x_4 + 0.114x_5 + 0.192x_6 + 0.233x_7 - 0.182x_8 + 0.055x_9 - 0.528x_{10} + 0.276x_{11} \quad (5)$$

The overall score model is calculated as follows:

$$Y = F1 * 47.576\% / 93.947 + F2 * 29.003\% / 93.947 + F3 * 17.367\% / 93.947 \quad (6)$$

The overall score model is:

$$Y = 0.201X_1 + 0.212X_2 - 0.138X_3 + 0.111X_4 - 0.019X_5 + 0.204x_6 + 0.130x_7 + 0.237x_8 + 0.282x_9 + 0.076x_{10} + 0.263x_{11} \quad (7)$$

In this model, the coefficient of every component is the weightiness of every indicator.

3.2.3 Calculating soil quality index

The soil quality index was calculated as follows:

$$SQI = \sum_{i=1}^n K_i \times C_i \quad (8)$$

Where SQI is soil quality index, C_i is the membership function value of indicators, K_i is the weightiness of indicators and n is the number of evaluated indicators.

The values of the soil quality index of *Caragana microphylla*, farmland, poplar, fallow land and the mixed plantation of *Caragana microphylla* and poplar were 1.410, 1.199, 1.284, 1.046, and 1.459, respectively (Fig. 4).

Compared with *Caragana microphylla* and the mixed plantation of *Caragana microphylla* and poplar, the value of the soil quality index of farm land was greatly reduced (Fig. 4), indicating that the soil degraded. Cultivation practices increased bulk density, and decreased enzyme activity, soil total nitrogen and organic matter content in soil. Although a lot of fertilizers including some available nutrients, e.g. Olsen P, were applied to the cropland, the soil quality could not be improved greatly. Application of fertilizer could only improve the contents of available nutrients.

The value of the soil quality index of fallow land was the lowest. In contrast with farmland, leaving land fallow could improve total nitrogen, total K, and organic matter content in soil. However, the comprehensive soil

quality of fallow land was lower than that of farmland. Analyzing and comparing every soil properties, we can see that the soil under fallow land had higher bulk density and lower total porosity than that of farmland.

It was further shown that growing *Caragana microphylla* and the mixed plantation of *Caragana microphylla* and poplar were the most sustainable ways of developing the Loess Plateau.

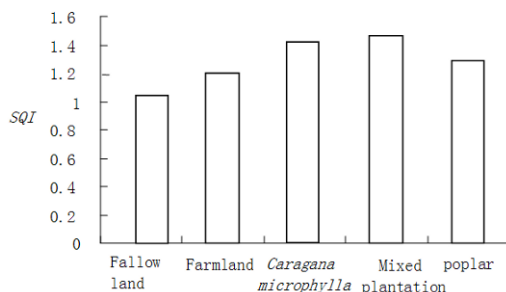


Fig4. Soil quality index values under different land use types

4. CONCLUSIONS

Plantations of *Caragana microphylla* and mixed plantations of *Caragana microphylla* and poplar can improve soil physical character, enzyme activity, and total nitrogen and organic matter content. The SQI of mixed plantations of *Caragana microphylla* and poplar was the highest of all and that of *Caragana microphylla* was the second highest. It was further shown that growing *Caragana microphylla* and the mixed plantation of *Caragana microphylla* and poplar provided the most sustainable ways of developing the Loess Plateau. Cropland soil was degraded, since cultivation practice increased bulk density, and decreased enzyme activity, soil total nitrogen and organic matter content in the soil. In contrast with farmland, land fallowing could improve total nitrogen, total K, and organic matter content in the soil. Considering the soil nutrient contents, land fallowing improved soil fertility to some extent.

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SPATIAL DIFFERENT ANALYSIS OF LAND USE/LAND COVER CHANGE AND HUMAN IMPACT IN TYPICAL OASIS IN ARID LAND

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Abstract: With the current problem of population, resources and environment becoming increasingly intense day by day, the land use/land cover change (LUCC) is one of the core topics on the Present World Change Study. And with the worsening of the global environment, the exhausting of energy and the population explosion, the controversy between the development of oasis economy and the environment has become more and more sharp, which has formed a serious threat to the sustainable development of the oasis economy. As a result, the reasonable, coordinate and continuous development is the experimental topic with great theoretical and practical significance in the world. Land use/land cover (LUCC) change has vital significance in environmental variation and the ecology monitoring in the arid and semi-arid areas. This article selects the typical oasis of Awat oasis, which is located in the upstream of Tarim River, where is a typical ecological fragile zone and environmental critical zone. Many effects are caused by the utilization of land and water resources. Along with further development and utilization, great changes of LUCC have been taken place. Based on the research on oasis-desert ecosystem, with the frontier theory of physical geography, LUCC of Awat oasis from 1990 to 2002 are analyzed through the technological train of 3S and statistics, and established the human impact index. Its influencing factors are also identified. First we take the farmland, the wood land, lawn, water, resident, wetland, salt alkali, sand land and naked land as a classification system. Based on the detailed analysis and pretreatment to the remote sensing imagery, we obtained relatively high precision classification

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result. By the quantification research of human impact to LUCC in Awat, it can be divided into the high human impact area and the low human impact area. The research shows that the changes of pattern are notable and human impact is continuously enhanced, and which is important for the sustainable development of Awat oasis. This research presents the evidence for harmonizing the relations between the land resource and the human activity and provides some methods and experiences for further study of LUCC in arid region.

Keywords: Land Use/Land Cover, human impact, spatial different, Awat Oasis

1. INTRODUCTION

Land use is an important factor of land cover change, and land cover change acts on land use in reverse. As the basis of human existing, and the main object of agricultural production, the status of land use/land cover not only influences the natural basis of human survival and development, but also closely relates with global climate change, evolution of the ecological environment, and the continuable connection between humanity and the environment that interacted with each other. So the land use/land cover is one of the main reason of global environment changes at present, and the core of all sustainable development either (Zhang Ming, et al., 2001; Bai Wanqi, et al., 2001; Tash polat Tiyp, et al., 2006; Li Xiubin, et al., 2002).

In the areas that sensitivity respond to environment, the strong interference from outside would result in abnormal change in ecological environment system. And the chain reaction of abnormal changes will be completely or partially change the natural environment (Louis-Albert Lake, et al., 2003; Marq De Villier, et al., 2002). People's role present many prominent impact on the Earth system by the complexity way, these effects interacted with themselves, as well as performance multi-pattern changes in local and regional scale, and make us unintelligibly, even difficult to forecast, and the mutation often occurred. Many academics at home and abroad have discussed the mechanism and laws of this change from many aspects (Louis-Albert Lake, et al., 2003; Marq De Villier, et al., 2002; Zhang Bo, et al., 2006; Du Lingtong, 2007). The south oasis of XinJiang is the region that human activity frequently and tempestuously, and it has an unique combination of community-economy-nature as well as the ethical culture. Quantitative research on driving force factors about LUCC in arid region are peopituous to the in-depth understanding of this system, clarifying the driving force mechanism of the land use change in arid region would lay a foundation for quantitating research on oasis stabilization, regional population, sustainable development of resources and environment.

2. LOCATION AND ENVIRONMENT

Awat County lies in the midwest of Xinjiang Uygur Autonomous Region and in the northeast of The Tarim basin, and south of the Tianshan Mountain. Locates north latitude $39^{\circ}31'$ to $40^{\circ}50'$, east longitude $79^{\circ}45'$ to $81^{\circ}05'$. This region major includes the Awat Country in Aksu Prefecture, and the area is $1.3 \times 104 \text{ km}^2$. The terrain is flat, and the north and the middle part are alluvial plain which belong to water landscape; and the south is desert plains the belongs to aeolian landforms. The climate here is warm temperate zone and arid weather of mainland. Aksu River, Yarkand River and the Hotan River intersect here, forming China's largest inland river---Tarim River. The economic development of this region mainly depends on agriculture, and that is an important grain and cotton bases of Xinjiang. But because of over-development causing the local ecological environment deteriorated, also has a certain impact on backward position.

3. METHODS

3.1 Data Acquisition

We selected Landsat TM data of the research region in May 1990 and in August 2002 as the main remote sensing data source and the 1:50000 digital grid map which is produced by National Foundation of Geography Information Centers and State Bureau of Surveying and Mapping. We then used the registration and geometric correction for ENVI 4.3 to geometrically correct, which made allowed the TM to match the base picture. We extracted the geographical information of the remote image by visual interpretation and use of maximum likelihood supervised classification on the basis of land using map. Selecting point from the results of interpretation at random to verify the accuracy, GPS points' attribute checking results show that land use types determine the accuracy rate of above 95%. The Arcgis 9.0 system was used to complete editing and revision of the resulting data. The data were then used to produce the vector map to obtain two group of data about land use; land types' division should reflect the western arid area oasis-desert ecosystem basic characteristics, and make the interpretation of remote sensing dates as the classification standards of land use, combining the characteristics of the research area, land use types can divide into nine categories: farmland, forestland, grassland, water area, residential area, wetlands, salinity, sandlot, bare areas.

3.2

Land use/Land cover Classification Index and Its Calculate Methods

In this research we introduce landscape ecology factor to statute and analyse the LUCC through Fragstats For Arcview.Although many landscape indexes have been published(Wu Jianguo,2000;Li Habin,et al.,1992;Chen Linding,et al.,1996;Wang Genxu,et al.,1999),we used the indexes listed in Table1 to evaluate changes in landscape pattern.

Table1. Landscape indexes and their formula

Landscape indexes	Abbreviation	Formula
Number of patches	NP	$NP = N$
Class area	CA	$CA = \sum_{j=1}^n a_{ij}$
Total area	TA	$TA = A$
Mean patch size	MPS	$MPS = A / N$
Percentage of landscape	PLAND	$PLAND = P_i = \frac{\sum_{j=1}^n a_{ij}}{A} \times 100\%$
Landscape diversity index	H	$H = -\sum_{i=1}^m [P_i \cdot \ln(P_i)]$
Landscape evenness index	E	$E = H / H_{\max} ; H_{\max} = \ln (m)$
Landscape dominance index	D	$D = H_{\max} + \sum_{i=1}^m [(P_i) \cdot \ln(P_i)]$
Landscape isolation index	S_i	$S_i = D_i / B_i ; D_i = 1/2 \sqrt{\frac{n_i}{A}} ; B_i = A_i / A,$
Landscape fragmentation index	C	$C = N / A ; C_i = n_i / A_i$

Where: N is the quantity of patch, a_{ij} is the total area of all patches in the landscape type I , A is the landscape's total area, P_{ij} is each patch's circumference,the m is the total amount of a type of patch in landscape,the P_i is the rate that a type of patch i appear in the landscape,the n_i means the total patch within the landscape type i .

3.3

Human Impact Index

The result of human activity is the primal and natural characteristics of land type falling down continually,different land types represent different human activity or the intensity of development and utilization characterstics(Wang Zhengquan,1999).Then according to the characteristics of the type of land use, we construct a human impact index to describe the intensity of human impact in a certain region.The calculate formula as below:

$$HAI = \sum_{i=1}^N A_i P_i / TA$$

Where,HAI is human impact index, N is the quantity of land use patch, A_i is the total area of all patches in the land use type I , P_i is the strength of the

human impact which reflected by land use components,TA is the total area of land use.

The strength indexes of human impact reflects the strength and attributes characteristics of different components of human involvement,management, transformation.In this study,Delphi methods is adopt to confirm the index(Table.2).HAI changes between 0 and 1,and the more the HAI is,the bigger human activities in the ascendant of land use are,and the bigger of human impact is,and vice versa.

Table 2. The strength indexes of human impact for different land use

Land use	Farmlan	Forestlai	Grassland	Water area	Residentia l area	Wetland	Salinity	Sandlot	Bare area
Delphi	0.54	0.09	0.24	0.12	0.96	0.15	0.38	0.24	0.08

3.4 Spatial analysis

The human impact index has the charactertics of spatial variability,so can use the geostatistics methods to analyse the spatial charactertics.The geostatistics is the methods of analysing the questions about spatial variable,basing on typical statistics,and considering the spatial variable and the spatial changes charactertics sufficiently(relativity and randomness),and taking variograms as tool(Wu Jianguo,2000;Wang Genxu,et al.,1999).Geostatistics can describe the human impact index of spatial structure clearly,thereby,can deeper understand the land use types which affected by spatial distributing and gradient changes and directional characteristics of humans’development and utilization,and using spatial interpolation methods can express the human impact status quantificationally as picture(Chen Fu,et al.,1999).

This research used the Kriging methods of geostatistics mainly,that is based on variogram theory and structural analysis.If the result shows relevance of space among the regional variables,then we can utilize the original data of regional variable and the frame of semi-variance function to evaluate the date that is linearly and optimally estimated without bias.Compare with normal methods,its advantage is maximize using the spatial information.

To ensure the human impact index of geostatistics can deputy the total status of human activities in certain area,in this paper,we used all the work area of grid for system sampling,each sample deputy as human activity,and the result as the center of samples.Generally believed that the type of land use should be 2-5 times of the mean patch size,then can reflect the pattern information of sampling area(O’neill R V,1996).According to the actual size of land use pattern patch in Awat Country,determining the sampling grid is 7km×7km.

On the basis of variograms,using ArcGis9.0 and block kriging produced the strength picture of human impact,so that we can discribe the spatial distribution of human impact directly in research area.

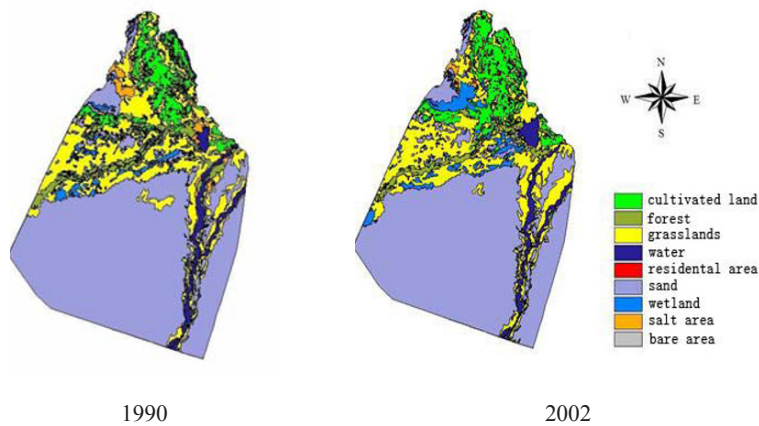


Fig.1: Landuse types of research area

4. CONCLUSION AND ANALYSIS

Awat oasis is a typical desert oasis which locates in west-arid region and lies upstream areas of Tarim River,its basic pattern is desert-oasis-river,as the Fig.1 express.The tab.3 and tab.4 reveals the land use/land cover of total landscape pattern and the changes of patches’ eigenvalue.

Table 3. Changes of characteristic values of landscape pattern in research area from 1990 to 2002

Index	Eigenvalue	
	1990s	2002s
TA (hm ²)	1295556.76	
NP	853	753
MPS (hm ²)	1518.8239	1720.5269
H	1.3018	1.2805
E	0.5925	0.6158
D	0.8954	0.7989
C	0.0658	0.0681

Table 4. Changes of characteristic values of landscape patches in research area from 1990 to 2002

Landscape	Year	NP	TA (hm ²)	MPS (hm2)	PLAND (%)	Si	C
Farmland	1990	60	86568.96	1442.8160	6.6820	0.0509	0.0007
	2002	50	119779.27	2395.5854	9.2454	0.0336	0.0004
Forestland	1990	174	77117.4	443.2034	5.9525	0.0595	0.0023
	2002	104	40637.97	390.7497	3.1367	0.0314	0.0026
Grassland	1990	172	285118	1657.6628	22.0074	0.2201	0.0006
	2002	148	279219.63	1886.6191	21.5521	0.2155	0.0005
Water area	1990	49	42576.19	868.9018	3.2863	0.0329	0.0012
	2002	36	42311.98	1175.3328	3.2659	0.0327	0.0009
Residential area	1990	73	854.27	11.7023	0.0659	0.0007	0.0855
	2002	195	6011.42	30.8278	0.4640	0.0046	0.0324
Wetland	1990	76	739622.27	9731.8720	57.0891	0.5709	0.0001
	2002	103	742886.65	7212.4917	57.3411	0.5734	0.0001
Salinity	1990	163	35801.91	219.6436	2.7634	0.0276	0.0046
	2002	92	58521.54	636.1037	4.5171	0.0452	0.0016
Sandlot	1990	78	27661.65	354.6365	2.1351	0.0214	0.0028
	2002	25	6188.23	247.5292	0.4777	0.0048	0.0040
Bare area	1990	8	235.1	29.3875	0.0181	0.0002	0.0340
	2002	0	0	0	0	0	0

4.1 Analysis on Land use / Land cover changes in landscape scale

According to Table 3 and Table 4,land use pattern of Awat oasis changed obviously between 1990 and 2002.From the analysis of the TM digital images extraction, the total area of land use is 1295556.76 hm²,the number of patch reduce between 1990 and 2002,and corresponding average area of patch is increasing from 1518.8239 hm² to 1720.5269 hm²,the added value is 201.703 hm².Shannon deversity index reduce from 1.3018 to 1.2085,but Shannon evenness index increase from 0.5925 to 0.6158.The decrease of dominance index indicates that the landscape structure of the whole area is controlled by some types of patches which has roughly equal proportion. Besides sandlot, farmland and grassland also have effect in controlling the whole landscape dynamically. The fragmentation of the landscape is in the tread of increased indicate that the interference of human is becoming harder.

4.2 Analysis on Land use / Land cover changes in patch scale

In study area, sandlot remains as the basic of landscape, accounting more than half of the total area.Between 1990 and 2002,its area increased by about 3.26 x 10³ hm²,the patch number increased from 76 to 103.Usually in environmental governance,only when the patch area and patch number become less and less, the strength of fragmentation about landscape type enhance constantly, can increase the degree of human environmental

governance to meet the requirements. Sandlot's pattern of the index can reflect changes when the local ecological environment hazards increasing.

The insides of Oasis, farmland, forestland and grassland larger in area. In 12 years, farmland area increased $3.32 \times 10^4 \text{hm}^2$, but the patch number changed little. Local farmers deforested, destructed the grass and reclaimed incessantly, so the area of artificial oasis expanded rapidly. The complexity of the patch had decreased, and their fragmentation and separation showed a downward trend, either. This was mainly due to the increasing area of farmland patch, the patch tend to be joint. Meanwhile, forestland and grassland continued to reduce, mostly as farmland, and were impacted by human activities increasingly, the instability enhanced.

The most obvious change is in the residential area. The number of patch is the most among all the types of landscapes, and increases to 122 during 12 years. Its area has expanded more than seven times. Artificial oasis area increasing, and the number of population growing rapidly affected settlements changes directly. So we can get that the shape of the residential area tends to rule, and the complexity declines, and the artificial landscape characteristics tend to prominence.

The wetland landscape, which received more and more attention in recent years, has many kinds of natural functions such as regulating regional climate, cleaning up the environment and maintaining the regional water balance, etc. However, the number of the wetland patch in the study area decreased from 163 to 92 during 12 years, the area increased. By contrast, the number of water body patch changed little and the area declined slightly. In practice, its natural waters' area reduced unceasingly, the regional water consumption increases leading to decline of the runoff and the expansion of artificial reservoirs made the proportion of the artificial waters to increase, thus the waters' overall change is not obvious.

The issue of soil salinization of the research area has improved during the 12 years. There is a large area of saline-alkali soil in the oasis interior and Oasis-desert transitional zone. The number and size of saline-alkali soil has a declining trend, accounted for the landscape proportion from 2.1351% in 1990 to 0.4777% in 2002.

Through the above analysis we can see that different types of landscape pattern index does not change with the overall change trend in sync. This shows changes in landscape pattern has the instability and the politropism characteristic, on the other hand also shows the human's operational flexibility in the future landscape pattern planning. Meanwhile the changing characteristics also demonstrated that it needs as many as possible interval materials to reveal the dynamic changes of the landscape pattern in trends and characteristics.

4.3 The spatial structure and distribution of human impact index

The human impact spatial analysis is completed by the geo-statistical method, which is based on sampling and calculating the experimental variable function of the human impact index and then fitting the theoretical semi-variable function. In the semi-variable function, since the results of spherical model is more satisfactory, the structure analysis of human impact index mainly based on spherical model, within the scale, the spatial distribution of all elements are self-correlated and the main ecology function, procession and pattern are all correlated with the scale.

Fig.2 is the study area's human impact index distribution figure, which is acquired by inserting the data based on the variable function analysis. It shows that, the man-made oasis system whose capital is Awat was highly affected by human, this region keeps the traditional agricultural landscape, the main form of human activity is the agricultural production. Human activities transform from a single agricultural production to the diversification of agricultural production, and the traditional agricultural landscape transform into a county and suburb hybrid landscape. Vast grassland, dune, and parts of water are nearly not influenced by human activity. Since the climate environment in the area is relatively poor, the influence of human activities is still in a relatively small state. But the trend is extending. Comparing the human-impact characteristics in 2002 to 1990, it has changed a lot, the highly influenced area has the current of spreading to the edge of the capital. The influence of human activities to Awat's land use is becoming larger and larger.

According to calculating the human impact index, we can see the highest data in 1990 is 0.529 and it is 0.577 in 2002. During the 12 years, the range of the human impact index extended and the degree of the human impact index increased too. At the same time, it can be found from the figure that: (1) the nearer the distance to the capital is, the higher the index is, and the further the distance is, the lower the index is; (2) along the Tarim drainage basin, the index is larger, while the index of the region far from the basin is low.

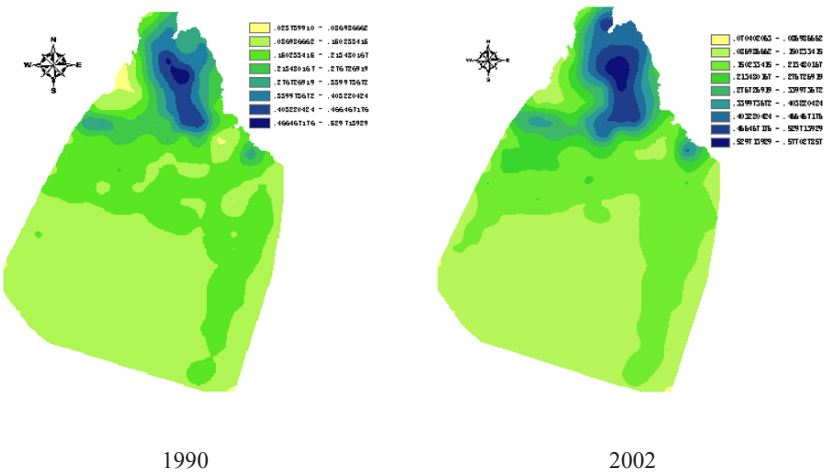


Fig.2: Spatial distribution of human impact indexes

5. CONCLUSION AND DISCUSSION

The unique soil and water conditions of the Awat oasis,which located in the upper reaches of the Tarim River,determine its suitability in the agricultural and livestock production.After the development of more than 50 years,artificial oasis formed gradually and at the same time the human development and utilization of regional land and water resources constantly expanding outward.Research shows that land-use pattern has undergone tremendous changes in the study area in 1990–2002:the landscape heterogeneity of the entire study area is declining,the degree of fragmentation is increasing.That indicates high development of the artificial oasis becomes the main type of landscape and human influences on ecological landscape is strengthening.Through the measurement of human’s activity index and spatial analysis,the highly influenced area by man’s activity is expanding unceasingly and the human influences on land-use of Awat County is becoming larger.

How to quantify the influence of human activity on land-use/cover changes is the hot issue of LUCC.Through constructing the man’s activity index of LUCC and spatial quantifying of the consequence in this study,gaining the human impact of changes in spatial variation and provides a valuable reference for further study on the relationship between human activities and the LUCC.

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THE POTENTIAL GEOGRAPHICAL DISTRIBUTION OF BACTROCERA DORSALIS (DIPTERA: TEPHRIDIDAE) IN CHINA BASED ON EMERGENCE RATE MODEL AND ARCGIS

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Abstract: The oriental fruit fly, *Bactrocera dorsalis* (Handel) (Diptera: Tephritidae), is the important insect pest of fruits and vegetables in tropical and subtropical areas. It is necessary to know the potential geographical distribution of this pest in order to monitor and control it effectively. Pupal development takes place in the soil and is regulated by two key factors; soil temperature and moisture. These factors are primary determinants of fruit fly distribution. In this study, the potential geographical distribution of *B. dorsalis* from Jan. to Dec. in China was predicted based on the soil temperature and moisture data of Chinese meteorologic stations, the ER (Emergence rate) model constructed from empirical biological data, and analysis with ArcGIS. The ER data were obtained by observing the emergence of 7560 cultured pupae using a crossover design of 7 soil temperature grades and 6 soil moisture grades. The ER model ($Z = -0.0036X^2 - 0.0001Y^2 + 0.1681X + 0.0123Y - 1.5170$) was established with stepwise regression method where emergence rate (Z) is a function of soil temperature (X) and soil moisture (Y). According to reported geographical

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distributions in the world, four categories were used to describe different levels of suitability for *B. dorsalis* in China, including negligible ($0 \leq ER \leq 0.01$), low ($0.01 < ER \leq 0.2$), moderate ($0.2 < ER \leq 0.45$) and high ($0.45 < ER \leq 1$). The potential geographical distribution and suitable levels for every month in China were obtained and showed that main parts of the distribution were south of $\pm 35^\circ\text{N}$, and most regions in China had high suitability levels from May to September. Further analysis showed the desirability of strengthening monitoring in the north parts of China from Apr. to Oct. and to institute whole year monitoring in Guangdong, Guangxi, Yunnan, and Hainan provinces.

Keywords: *Bactrocera dorsalis*, potential geographical distribution, emergence rate, plant quarantine, ArcGIS

1. INTRODUCTION

The oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae), originates from Taiwan and Ryukyu Islands and is a serious quarantine pest of fruits with a wide host area in tropical and subtropical countries (Huang Suqing et al., 2005). *Bactrocera dorsalis* has reportedly spread abroad to about 20 countries in North America, Oceania and Asia by IIE (International Institute of Entomology) as well as Europe and the Mediterranean Plant Protection Organization (IIE, 1994). In addition, *B. dorsalis*' host is continually expanding; 150 host species in 1960 (Christenson et al., 1960), 250 species in 2003 (Liang Guanghong et al., 2003) and in 2005. Presently, this fruit fly infects more than 300 species of fruits and vegetables from 46 families in southern provinces of China like Fujian, Hainan, Guangdong, Guangxi, Hunan, Guizhou, Yunnan, and Sichuan (Huang Suqing et al., 2005; Huang Kehui et al., 2005).

The oriental fruit fly can have three to eleven generations yearly in China, but mainly has four to eight generations, and its growth periods were 19d under 24°C , and 32.5d-35d under 33°C in Yunnan province. The emergence rate of oriental fruit fly was between 80% and 90% in these areas. However, overwintering is variable and many generations are staggered resulting in different insect states occurring at the same time and place (Liang Guanghong et al., 2003; Liang Guangqin et al., 1993; Zhang Qingyuan et al., 1998; Zhou Yousheng et al., 1996; Jiang Xiaolong et al., 2001).

Knowledge of the geographical distribution of insect pests is necessary to properly monitor and manage them. Consequently, suitability analysis methods have gained attention in recent years. Suitability analyses are estimated from simple ecological estimates, climographic analysis (Cook et al., 1921, 1931), similarity distance of agricultural climate (Wei Shuqiu,

1984), Geographical Information System (Wu Yufen, 2005), Ecological Niche Models (Wang Yunsheng et al., 2007), CLIMEX (Sutherst et al., 1991, 2005; Song Hongmin et al., 2004; Stephens et al., 2007 ; Hou Bohua et al., 2005; Chen Lin et al., 2006), GARP (Zhou Guoliang et al., 2007), DIVA-GIS (Ge Quanqing et al., 2006 ; Hernandez, 2006), MAXENT (Elith et al., 2006; Wang Yunsheng et al., 2007) and so on. Moreover, software based on ecological niches including BIOMAPPER, BRT, GAM, GLM. The characteristic of these methods was more accurate and more simply than ever because many suitability analysis methods are based on exact software and comprehensive influence factors of corresponding pest.

Several methods have been used to predict the potential geographical distribution of oriental fruit fly. The first used fuzzy mathematics (Zhang Runjie et al., 2005) and showed that the potential geographical distribution of *B. dorsalis* in China occurred in regions south of 25°N including the Sichuan basin and part of Guizhou province. The region between 25°N and the Changjiang River was less suitable, and other regions of China were unsuitable (Fan Jinan et al., 1998). The second method used CLIMEX and showed that the most suitable areas are in South China including Guangdong, Hong Kong, Hainan and Guangxi Zhuang Autonomous Region, moderately suitable areas includes Yunnan, Sichuan, Southwest China and some parts of Fujian province, the suitability drops in some parts of Hunan, Hubei, Jiangxi and Zhejiang provinces. Unsuitable areas included the northern part of the Yangzi River (Hou Bohua et al., 2005). Stephens et al (2007) reported the current and future potential geographical distribution using CLIMEX, but the prediction did not align well with real distribution, especially in Shanghai (Zhou Guoliang, 2006). The third method was based on the fly's fatal temperature, accumulated effective temperature and bioclimate analogous distance. It showed that the viability areas were 31.64% in China, the Northern distribution threshold was nearly (30±2)°N (Wu Yufen, 2005). The fourth method used GARP ecological niche modeling to predict potential ecological distribution of *B. dorsalis* in China. The results showed host fruit plants have been cultivated at high densities in both suitable and sub-suitable areas, and the major potential geographical distribution of *B. dorsalis* was concentrated south of Changjiang River (97.4°E-121.9°E, 18.2°N-33.0°N) (Zhou Guoliang, 2007).

Among factors affecting the potential geographical distribution of insect pests, temperature is considered the most pivotal (Ren Lu et al., 2007). As a serious insect pest, a lot of researches are focus on biological characteristics of *B. dorsalis*. Pupal development takes place in the soil and is regulated by two key factors; soil temperature and moisture. These factors are primary determinants of fruit fly distribution. The adult *B. dorsalis* emerges between

10.08°C-33.3°C (Wu Jiajiao et al., 2003), Vergas reported that the threshold temperature for pupae of *B. dorsalis* was 9.3°C (Vergas et al., 1996); Hsu reported 11.1°C (Hsu et al., 1973); and Wu Jiajiao reported 10.08°C (Wu Jiajiao et al., 2003). The emergence rate of *B. dorsalis* was highest when relative soil moisture was between 30%-80% (Yuan Shengyong et al., 2004; Lin Jintian et al., 2005). The aforementioned research used atmospheric temperature and soil moisture estimated from rainfall instead of direct measures of soil temperature and moisture which may misestimate the distribution of *B. dorsalis*. Furthermore, soil temperature and moisture vary over 12 months, so this variability should be addressed.

In the present study, the potential geographical distribution of *B. dorsalis* from January to December in China was predicted based on soil temperature and moisture data from Chinese observation stations, the ER (Emergence rate) model which is based on biological observations and statistical analysis, and analysis using ArcGIS. In addition, four typical monitoring periods of *B. dorsalis* in China are detailed according to the prediction of potential geographical distribution and suitability levels.

2. MATERIALS AND METHODS

The two parts of this study include establishing the ER (emergence rate) model of *B. dorsalis* and analyzing the potential geographical distribution and suitability levels using the ER model and displaying distribution patterns using soil temperature and soil moisture of past years in China on an ArcGIS platform.

The *B. dorsalis* samples collected from Huangpu in Guangdong province were selected for the emergence experiment. Eggs of *B. dorsalis* were obtained from adults that had been reared for four generations on artificial diet. Mature larvae (6 days after egg hatch) were placed in moist sand (75% water) at 29°C for pupation. All 7560 pupas were gathered after 24h under and held at 25°C.

The emergence rate (ER) data was collected by placing pupae in a plastic box (high 7cm, diameter 12.5cm) containing medium soil (Guangdong, DaHan) in an Artificial Climate box (Germany Binder Kbwf240). Data was analyzed using SPSS13.0 (<http://www.seekbio.com/soft/1492.html>) and ArcGIS 9.0 (Environmental Systems Research Institute. ESRI). Soil temperature and moisture (2001-2003) were obtained from China Meteorological Administration.

The ER model, based on soil temperature and relative water content was obtained from a crossover design experiment conducted from March 2007 to

August 2007 at the plant quarantine lab of Guangdong Entry-Exit Inspection and Quarantine Bureau. The design specified 7 soil temperature grades; 9°C, 14°C, 19°C, 24°C, 29°C, 34°C and 39°C. Six relative water content grades included 0%, 20%, 40%, 60%, 80%, and 100%. Experiments consisted of 46 treatments and 3 replications during about 25 days and every box had 60 pupaes. All pupaes were placed 2cm under the soil and held in artificial climate boxes. Water was added as needed (Wu Qianhong et al., 1991).The ER of *B. dorsalis* was got and. the ER model was derived by stepwise regression (SPSS 13.0)

Geographic distribution and suitability was calculated for each month of the year for all of China and displayed as maps in ArcGIS. Soil temperature and moisture data were limited, but at least 10 days per month was obtained. Since values were obtained from different locations in different months, the full data set is presented in Table.3. The suitability of *B. dorsalis* was analyzed on the basis of these data and ER model results. The ER of *B. dorsalis* for every location in China was obtained. For each location, suitability was categorized into 4 levels; negligible (where the *B. dorsalis* is unable to occur and survive) ($0 \leq ER \leq 0.01$), low ($0.01 < ER \leq 0.2$), moderate ($0.2 < ER \leq 0.45$) and high ($0.45 < ER \leq 1$). Suitability maps were plotted for each month using the inverse distance weight (IDW) raster interpolation.

3. RESULTS

3.1 ER model

Stepwise regression analysis results:
Stepwise regression ordered the independent variables according to their explanatory power. X^2 improved r^2 the most followed by X, Y and Y^2 (Table.1, Table.2). Analysis showed that XY did not contribute to the explanatory power of the model, so it was dropped.

Table 1 Regression model summaries

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.2014(a)	0.0406	0.0328	0.3888
2	0.7843(b)	0.6151	0.6088	0.2473
3	0.8080(c)	0.6529	0.6443	0.2358
4	0.8471(d)	0.7175	0.7082	0.2136

Table.2 Analysis of variance of regression

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	0.7928	1.0000	0.7928	5.2442	0.0237(a)
	Residual	18.7447	124.0000	0.1512		
	Total	19.5375	125.0000			
2	Regression	12.0169	2.0000	6.0085	98.2699	0.0000(b)
	Residual	7.5205	123.0000	0.0611		
	Total	19.5375	125.0000			
3	Regression	12.7555	3.0000	4.2518	76.4859	0.0000(c)
	Residual	6.7820	122.0000	0.0556		
	Total	19.5375	125.0000			
4	Regression	14.0185	4.0000	3.5046	76.8360	0.0000(d)
	Residual	5.5190	121.0000	0.0456		
	Total	19.5375	125.0000			

a Predictors: (Constant), xx / b Predictors: (Constant), xx, x / c Predictors: (Constant), xx, x, y / d Predictors: (Constant), xx, x, y, yy

Table .1 shows regression model summary, four constants are available including XX, X, Y and YY. Table.2 shows two constants are very significant because of $F=98.2699>F_{0.05}$ including XX and X, three constants are significant $F=76.4859>F_{0.05}$, four constants are significant $F=76.8360>F_{0.05}$.

The model was available because of $R^2=0.718$, $F=76.836>F_{0.05}$ and $P<0.01$. The regression analysis of the ER showed that P was significant on 0.01 level.

The model chosen for emergence rate determination was
 $Z = -0.0036X^2 - 0.0001Y^2 + 0.1681X + 0.0123Y - 1.5170$

Where:
Z is the ER (emergence rate) of *B. dorsalis*
X is the soil temperature
Y is the soil moisture

3.2 Potential geographical distribution of B. dorsalis in China:

Meteorological locations analysis in China: From the Table.3.

As the basis of this model, *B. dorsalis* suitability was analyzed for 12 months in China combining with the soil data from 2001 to 2003. Since different locations were used by the China Meteorological Service to determine soil temperature and moisture, percents of suitable locations were analyzed. From January to April, moderate and low levels were declining and high levels were increasing, which was the reverse trend from Nov. to Dec. From May to Oct., levels remained stable. It was obviously that two

suitable high points were May and Sep., high level was the topmost in whole year, both locations and suitable locations were comprehensive from May to Oct.. There was a turning point in Jul., high suitability levels declined, and other levels increased. This is in accord with the *B. dorsalis* biology because soil temperature and moisture is beyond its tolerance.

Table.3 Meteorological locations analysis (Percents of Suitable locations (%) = Suitable locations / locations Percents Of five grades (%) = Numbers of suitable locations/ Suitable locations)

Month	Locations analyzed	Suitable locations	Percents of Suitable locations (%)	Suitability levels	Frequency within suitable locations	Percents within each level (%)
1	43	7	16.28	high	2	28.57
				moderate	1	14.29
				low	4	57.14
2	78	9	11.54	high	2	22.22
				moderate	6	66.67
				low	1	11.11
3	105	40	38.10	high	12	30.00
				moderate	10	25.00
				low	18	45.00
4	103	84	81.55	high	42	50.00
				moderate	31	36.90
				low	11	13.10
5	103	102	99.03	high	100	97.09
				moderate	1	0.97
				low	1	0.97
6	103	103	100	high	99	96.12
				moderate	3	2.91
				low	1	0.97
7	103	97	94.17	high	63	64.95
				moderate	33	34.02
				low	1	1.03
8	93	93	100	high	88	94.62
				moderate	5	5.38
				low	0	0.00
9	103	102	99.03	high	93	91.18
				moderate	9	8.82
				low	0	0.00
10	102	69	67.65	high	33	49.25
				moderate	17	25.37
				low	19	28.36
11	100	21	21.00	high	6	28.57
				moderate	5	23.81
				low	10	47.62
12	57	8	14.04	high	2	25.00
				moderate	1	12.50
				low	5	62.50

Four months (Feb., Mar., Jul. and Oct) had visible change. Each map indicates the geographic distribution of each suitability level.

The February map showed that the suitable areas were concentrated on the south of China including Yunnan, Sichuan, Guizhou, Guangdong and

Hainan. High level suitable areas were the south of Yunnan and southwest of Guangxi.

The Mar. map suitabilities are similar to reported local observations except for the southeast of Shandong including Laiyang (moderate level, 36.58°N), Weifang (moderate level, 36.45°N) and Ivxian (high level, 35.35°N), which foreshadoows *B. dorsalis* spreading from the south to the north year by year in China because from its last reported latitude of 33°N (Zhou Guoliang et al., 2007) (Fig.1) .

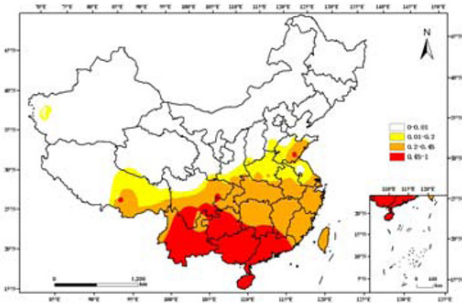


Fig.1: Mar. The potential geographical distribution of *B. dorsalis* and four levels including negligible ($0 \leq ER \leq 0.01$), low ($0.01 < ER \leq 0.2$), moderate ($0.2 < ER \leq 0.45$) and high ($0.45 < ER \leq 1$)

The July map showed that the north of Jiangxi and the west of Hubei were low level suitable areas due to soil temperature and moisture being very high, a limitation showed by the ER. Likewise, the map showed the major areas of moderate level suitability in the south of China.

From the map of Oct. about suitable information of *B. dorsalis*, the results showed the north of China including Heilongjiang and Jilin were negligible. Suitable areas were reduced from the north to the south of China. But the east of Xinjiang including Shache (38.26°N) which was ought to be regarded was high level suitability. Maqu (34°N) from Gansu province was negligible because its soil temperature was very low. (Fig.2)

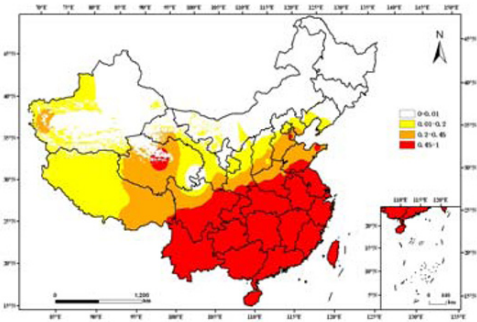


Fig.2: Oct. The potential geographical distribution of *B. dorsalis* and four levels including negligible ($0 \leq ER \leq 0.01$), low ($0.01 < ER \leq 0.2$), moderate ($0.2 < ER \leq 0.45$) and high ($0.45 < ER \leq 1$)

3.3 Conclusions

This study confirms other research as well as observations of *B. dorsalis* distribution throughout China. Major suitable locations occur south of $\pm 35^{\circ}\text{N}$ with little occurrence north of 35°N .

The distribution expanded and contracted over the year with the wider distribution occurring in the summer months. Environmental conditions in high level locations correlated with optimal development conditions predicted by the emergence rate model. The results indicated that soil temperature affected the potential geographical distribution of *B. dorsalis* in China and suitable areas changed with the season.

In winter months the suitable areas for *B. dorsalis* in China were concentrated in south China, such as Yunnan, Guangxi and Guangdong. In March, *B. dorsalis* started to spread from south to north. At the beginning of April, the suitability of *B. dorsalis* was high in south China, where 81.55% of the locations were suitable. In that area suitability was rated high (50%) and moderate (36.9%), indicating that pest management actions against *B. dorsalis* should commence at this time. From May to December, major portions of China contained suitability areas, but it was obvious from the map that suitability in south China declined in July from high to moderate because soil temperatures exceeded the emergence threshold temperature of *B. dorsalis*, and high rainfall frequency in this period suppressed emergence.

4. DISCUSSION

4.1 The potential geographical distribution analysis of *B. dorsalis* in China

Yunnan suitability analysis: Yunnan was one of the important suitable areas during winter months and provided the source population of *B. dorsalis* for the coming year with adult populations peaking in July. This was also reported by Jiang Xiaolong and Chen Peng (Jiang Xiaolong et al., 2001; Chen Peng et al., 2007). The results indicated that Menzi (a county of Yunnan) didn't occur seasonally, which was different with Liuku (a county of Yunnan) in province, the south of Yunnan especially Menzi was suitable for occurring of *B. dorsalis* in whole year (Chen Peng et al., 2007). Hei Longjiang suitability analysis: Hei Longjiang areas have high suitability from May to September, however, these results are misleading since *B.*

dorsalis cannot survive the winter in this area. Shanghai suitability analysis: *B. dorsalis* emergence may happen at the beginning of April, but was highest from May to October. This correlates with the report of Zhou Guoliang who found progressively earlier emergence over several years. The fruit fly was found firstly in August in 2001, in June in 2002, in June in 2003 and in May in 2004 and 2005 (Zhou Guoliang, 2006). Qinghai, Tibet and Xinjiang areas suitability analysis: Suitability was high from May to September, but the results could not be substantiated because of the lack of host plants and a difficult winter.

4.2 Monitoring and trapping periods

This study indicated four monitoring and trapping periods for fruit fly emergence in China. Two months are not suitable and monitoring should be suspending at these times. The first period was from April 1 to October 31, and monitoring areas include Liaoning, Jilin, Heilongjiang, Inner Mongolia, Qinghai, Beijing, Tianjin, Hebei, Henan, Shandong, Shanxi, Shaanxi, Gansu and Ningxia. The second period, from March 1 to October 31 included Xinjiang, Zhejiang and Tibet. The third period was from March 1 to November 31 and included Sichuan, Chongqing, Guizhou, Jiangxi, Hubei, Hunan, Anhui, Jiangsu, Shanghai, Fujian and Taiwan. Monitoring should take place throughout the year in Guangdong, Guangxi, Yunnan, Hainan.

In summary, we reported that two important natural factors (soil temperature and moisture) determined the potential geographical distribution of *B. dorsalis* over 12 months in China, and that the ER model can be used to predict where and when these conditions are suitable for F emergence. This model may also apply to other countries. The ER model will be improved with future research.

4.3 Management countermeasures

Quarantine measures should be strengthened domestically as well as at the borders (inspection and quarantine). The critical tasks of border inspection and quarantine are port inspection and quarantine from May to September, especially from imports from these continents: America (America, Chile), Oceania (Australia, New Zealand, Nauru), Asia (Bangladesh, Bhutan, Hindustan, Kisan, Japan, Laos, Malaysia, Burma, Nepal, Oman, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, United Arab Emirates, Viet Nam), because many areas of China are suitable for fruit fly during this time. In addition, domestic inspection and quarantine should address the transport of fruits and vegetables from south China to areas in the north, such as

Guangdong, Guangxi, Hunan, Guizhou, Fujian, Hainan, Yunnan, Szechwan, Hongkong, Macao, Taiwan and so on. Quarantine measures ought to be reinforced to prevent fruit and vegetable infestations.

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CONSTRUCTION STANDARD OF FARMLAND LANDSCAPE PATTERN IN CHINA BASED ON PRECISION AGRICULTURE

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Abstract: Precision agriculture is an important choice for the future agriculture. It is the base for precision agriculture development to change the state of small-scale farmland production and weak agricultural foundation in China gradually. Combined with the poorness of village in China, the variation of farmland and the dominance of small-scale peasant economy, this paper analyzed the adaptability of farmland landscape pattern to precision agriculture based on literatures and farmland landscape survey. With the requirements of precision agricultural production, this paper put forward the standards on cultivated field scale and shape, farmland corridor structure, cultivated field matrix and farmland landscape protection in order to make farmland landscape suitable for precision agriculture and to provide references for the sustainable development of precision agriculture in China.

Keywords: precision agriculture, farmland landscape, agricultural mechanization, agricultural modernization

1. INTRODUCTION

Farmland landscape pattern is the product of long-term integration of nature, society and agricultural production technology, which shows variable natural, cultural and technical characteristics. With the deepening of

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ecological civilization conception, the scientific development concept makes a higher demand of farmland landscape pattern, and protecting and improving rural farmland landscape have become the historical responsibility in agricultural modernization construction. Precision agriculture with sustainable development is the core of agricultural modernization construction. It requires more to farmland landscape pattern than the mechanized simply agriculture, which can be seen not only in field size, shape and leveling degree, but also in the structure of farmland landscape pattern. Obviously, the farmland landscape pattern suitable for agricultural mechanization is just the basis of sustainable precision agriculture. However, the small scale fields, low level of agricultural mechanization and poor facilities in China have hindered the construction of precision agriculture. It is necessary to rebuild the existing farmland landscape pattern objectively.

2. TRADITIONAL FARMLAND LANDSCAPE PATTERN AND EXISTING PROBLEMS

After a long-time historical vicissitudes, farmland landscape pattern characterized with “Well field” was formed. The long-term petty-farmer management and private ownership of property right in feudal society made the field scale small and the boundary irregular. Autarkical or half-autarkical small-scale family farming lacks the ability to resist the nature disaster. Before the foundation of New China, the farming scale formed in rural areas in China. But because of the scattered highly land use right, the agricultural productivity was very low, it was so hard to irrigate in dry days or to drain in rain days that farmers relied on the nature, which caused wasted land and field full of weed. For example, in Baoding County in Hebei province, each farming family had an average area of 1.05hm^2 , and each was cut into 20 pieces. And in Wuxi County in Jiangsu province, each farming family had an average area of 1.05hm^2 , and each was cut into 15 pieces.

Before the Rural Producer's Cooperative was established, the area of private land owned by farmers was often small, which was composed of small scattered fields and narrow pieces. After 1949, farmland was centralized. In 1955, the Cooperative Movement was developed quickly and the "1956-1967 National Agricultural Development Outline (Draft)" was issued which made "Reclaiming wasteland, expanding cultivated land area" as one of the important goals ([General Administration of Land use, 1956](#)). To eliminate one field inserting, wedging, far from and replaced by another field, it is necessary to make the farmland centralized and the shape regular, which adapt to the requirement of production. Therefore, the planning and project “Square field and strip field” were carried out in plain areas, and the

planning and project “Terrace field” were carried out in mountainous areas. Meanwhile, farmland was centralized and regulated, soil was improved, and ancillary field roads, sheltered belts and irrigation channels were constructed, which all laid the foundation for the initial formation of intensive farmland landscape pattern.

The traditional mode of agricultural technology also selects species and monitors soil fertility on regional scale and accumulates the cultivation and management measures suitable for local conditions, which are recommended to farmers. In fact, even in the same field, there are obvious space-time distribution differences of crop growth conditions and yield on and below the ground, including crops diseases, insects and weeds in the fields, which always happen in the form of patch in an area and then gradually spread and change in time and space. That farmers divide cultivated land into small pieces was restricted to the emotional knowledge to crop growth environment and yield spatial variation. Thus, production management experience of “Traditional precision farming” was formed. However, it is impossible to form large-scale productivity because of the supportive lack of quantitative researches of modern scientific methods and modern engineering means (Chen Deen et al., 2008).

(1) Scattered land property right and small-scale cultivated field

The implementation of the household contract responsibility system in the mid-1980s reduced the average operation scale of each farming family (Zhao Yanwen et al., 2007). In Yangzhong of Jiangsu, the total area of farmland patches decreased 3% from 1999 to 2004, while the number of patches increased to 369, 73.8 patches increased each year on average. The patch density increased from 8.07 patches per km² in 1999 to 9.48 in 2004 (Li Xintong et al., 2000).

The scale of agricultural production based on the unit of farming family is often small, and the fertilizer and management levels of different farmers are differences, and soil nutrients in fields change greatly in space. Therefore, it is difficult to draw a spatial distribution map of soil with sub-meter precision and to make variable rate fertilizer precisely (Chen Fang et al., 2006). Since the division state caused by the household contract responsibility system is definitely not suitable for the development of precision agriculture, it is necessary to reform the land management mode (Lei Yu et al., 2007).

(2) Extensive management and low efficient use of resources

The effective utilization rate of water resources is only 45% in China, while 50%-70% in developed countries. It's an important direction for agricultural resource use to fertilize precisely according to soil moisture condition in fields and to increase water utilization rate to the greatest extent. The utilization rate of chemical fertilizer in China is also quite low, between 30% and 40%. And the loss rate of nitrogen reaches up to 70%-80%. The

chemical fertilizer waste is very serious, which caused many environmental issues. To implement precision agriculture and to fertilize precisely according to the soil nutrients will save greatly the usage of chemical fertilizer and reduce investment (Liu Yanxuan et al., 2007).

(3) Weak protection and biodiversity

Agricultural civilization in China shows the bright shine. In the course of thousands-year development, rural ecological civilization with different regional characteristics has formed. But in the process of farmland construction and development, people emphasized on the intensive use of farmland but ignored the protection of agro-ecosystem, which caused the crop variety and planting patterns single. To emphasize pesticides and chemical fertilizer but to ignore ecological treatment and straw back into field caused the biodiversity declined sharply and the stability of agro-ecosystem weakened.

In short, resources in China are limited, and the contradiction between human and land is obvious, and natural disasters happen frequently, and there is too much draught, barren and saline-alkali soil. Therefore, the overall condition of agricultural production is poor. And it's hard to meet the requirements to support the practice and management of modernized agriculture by information technology, to decide the input on the crop based on the soil properties as well as temperature, humidity, light and other factors, to diagnose cultivated land and growing way of crops in quantity and real-timely, to improve soil productivity and to realize precision agriculture with high quality, high yield, low consumption and environmental protection (Lei Weiwei et al., 2008; Zhao Wei et al.,2008; Wang Maohua,1999; Zhao Chunjiang et al.,2003). Obviously, it is necessary to rebuild the existing farmland landscape pattern.

3. CULTIVATED FIELD SCALE AND SHAPE

Agricultural mechanization requires proper scale and shape of cultivated field to improve the efficiency of agricultural machine operation and to reduce the degree of damage to the soil structure. Precision agriculture supported by mechanization has higher requirements on the scale and shape of cultivated field, and the requirements under different agricultural operation methods differ.

3.1 Scale and shape of cultivated field in plain areas

The scale of farmland operation in China is small. The level of agricultural mechanization is low. There is still a long road of development

process to implement wide-area precision agriculture. Plain area is flat, densely populated, has complete infrastructure relatively and is basically able to adapt to agricultural mechanized operation after long-term farmland construction. It's the best area to develop precision agriculture in advance recently. It corresponds with national conditions of China to develop precision agriculture in large-scale farms and plain areas with large-area crop production.

(1) Scale and shape of cultivated field with mechanized operation

Mechanized operation can exert the mechanical efficiency only if fields meet the requirements of machine operation. Precision agriculture makes following requirements to cultivated field:

Cultivated field scale: Precision agriculture was put forward to adapt to the sustainable development of crop production system with highly intensive and scale degree. And the marginal effect is positively related to operation scale. In addition, precision agriculture such as sampling and testing soil is clearly inappropriate to the situation of plot operation in China, which makes the accuracy declined. Therefore, cultivated field should be in proper scale to meet the need of precision agricultural production. The length is designed to bring machines into full play. Generally, the longer the field is, the fewer the time that the agricultural machines turn is and the higher the efficiency is. Considering the requirements of irrigation, drainage and windbreak, the field length in plain areas is commonly 500m-800m; the field width is multiple of that of machine operation, 200m-400m, and the ratio between perimeter and area is controlled within $60\text{m}/\text{hm}^2$ - $300\text{m}/\text{hm}^2$. Taking fertilizing wheat as an example, according to the analysis of economic benefit, the minimum area of cultivated field, which is appropriate for technical practice of precision agriculture and feasible economically is 85.6hm^2 (Li Shicheng et al., 2007). High agricultural mechanization promotes the appropriate scale of land operation.

Scale of paddy field is smaller than that of dry land. In terms of precision agricultural management, the field area is 0.5hm^2 to 1.5hm^2 .

Cultivated field shape: In order to set good conditions for machine operation, the field shape should strive to be regular and take rectangular and square as the best followed by right-angle trapezoid and parallelogram. And the worst are irregular triangles and arbitrary polygon. The patch shape index should be close to 1. And the field orientation should be good for machine operation, generally the north and south (Bao Haijun et al., 2002).

(2) Scale and shape of labor-intensive cultivated field

To save resources and to improve the efficiency of resources use are both the mission of labor-intensive agriculture. And precision agriculture provides it with technical support.

Scale and shape of labor-intensive agriculture for industrial production should be in accordance with the production process. Cultivated area of agriculture taking plastic warm shed and energy-saving sunlight greenhouse as main facility has reached nearly $20.0 \times 10^4 \text{hm}^2$ in China, which is No.1 in the world. Nevertheless, there is still a large gap about the whole level of facility production between China and developed countries, which can be seen on poor facilities, low technical contents, poor control of light and temperature, especially computer management difficult to support. Thus, agriculture can not be regarded as precision cultivation and needs to construct supported facilities in accordance with the production process.

Scale and shape of open-air labor-intensive cultivated field should adapt to characteristics of the labor. Generally speaking, the area should not be too large and the pattern should not be too complex. It can be divided by the field roads based on mechanized cultivated field to meet the requirements of labor operation.

3.2 Scale and shape of cultivated field in hilly areas

The landform is obviously undulated in hilly area. Except flat farmland in valley, most farmland is terrace field. Low agricultural mechanization and high cost of precision cultivation make it an area difficult to develop precision agriculture. Although the hilly area is unsuitable for development of precision agriculture temporally, it's still feasible to exert some functions of precision agriculture in this area gradually. Under the precondition of keeping the stability of regional ecosystem, scale and shape of farmland in hilly area can be set by the slope. Terrace fields are developed based on road system or irrigation and drainage channel system as framework. The direction should follow the contour, and the shape should be square, rectangular or trapezoidal and the area should be 5hm^2 - 6hm^2 .

4. STRUCTURE OF FARMLAND LANDSCAPE

With the development of modern agriculture, agricultural mechanization promoted the intensive use of farmland. Small and scattered patches (such as forest land, shelterbelts, channels, grassland) disappear largely from modern agricultural landscape. In the past 58 years, in order to increase agricultural production, a lot of farmland corridors were eliminated and the farmland scale was expanded continually, which caused the great changes of farmland landscape (Croxtton et al., 2002). With the increase of agricultural mechanization, field marginal zone reduced sharply, for example, the density of shelterbelts and channels reduced (Cœur et al., 2002). Field roads for

small agricultural tools, people and livestock will be consolidated into farmland. Some other field roads will be widened to be suitable for large agricultural machines. And farmland patch scale surrounded by wide corridors will be expanded. Water resources amount is a key factor to determine the structure of precision farmland landscape corridors.

(4) Structure of farmland corridors in water-short area

Water-saving irrigation is an important measure for sustainable development in water-short area. Precision irrigation is apparently out of what channels can do. It needs laying water pipes and supported water-saving facilities.

Dry farming area: Considering saving water, in order to reduce occupied land, it is necessary to fix up the drainage channels as underground pipes when laying water delivery pipes. In the areas with large surface runoff, drainage or stain, lateral canals and some field ditches can be reserved properly. In the area with wind damage, protection forest should be laid out according to the requirements of wind precaution. Production road should be laid out according to the requirement of production in accordance with channels, pipes and protection forest.

Paddy farming area: The composition of paddy field corridors is basically as the same as that of dry field corridors. Water delivery should adopt pipes, and drainage should adopt open ditches, and protection forest should be laid out according to the requirements of disaster prevention.

(2) Structure of farmland corridors in water-rich area

In water-rich area, paddy field is the main part of farmland. And the core of precision agriculture is fertilizer, control of plant diseases and insect pests and field management. The requests to structure of corridor are land saving and supported facilities.

(3) Composition of farmland marginal line

Intensive farmland is usually to cultivate uniformly in a large area of land. Due to great spatial variability of land, single uniform farming results in land degradation and low efficiency of protection measures. Precision agriculture can protect soil and reduce environmental hazards on the basis of continuing high-yield (Bai Yi, 2007). Therefore, between fields and water channels establishing permanent vegetation zone along and level to the sides of fields can hold up and slow down the runoff, improve infiltration, reduce the water pollution of chemical substances on the lower reaches of the stream and protect farmland ecological security.

(4) Cultivated field matrix

Cultivated field matrix mainly contains soil conditions, land leveling degree and farming method. Soil is the site of material, energy and information exchanges for crops. Soil conditions are mainly texture and fertility. Soil with poor texture needs soil improvement design and

fertilization design. Surface soil thickness is highly related to the yield of crop. In the construction of precision agriculture, surface soil should be protected (Wu Fei et al., 2006). Land leveling degree directly impacts intensive cultivation, irrigation, drainage, crop ventilation and photosynthesis, which aim to flatness. Farming method is mainly rotation method, which aims to raise productivity through crop rotation.

Field leveling height should adapt to local conditions, invest less, and be proper for irrigation and drainage and mechanized cultivation. The elevation design of farmland that harvests even in flood or dry seasons with small undulating landform and thick soil should be determined mainly in accordance with the requirements of fill and excavation volumes; the elevation design of sloping field with large undulating landform and thin soil should not only consider leveling earthwork volume but also try to meet the requirements of irrigation and drainage facilities according to landform features; the elevation design of low bottomland should also take requirements of water level into consideration, and the elevation after leveling should be 0.2m higher than annual flood level. For the farmland with high water level, the field elevation should be designed 0.8m higher than annual ground water level (Fu Meichen et al., 2007). Inner height differences of paddy field should be controlled within 3cm

(5) Protection and development of farmland landscape

Through study of relationship between farmland yield and production input and field scale, Indra Roschewitz et al. said that farmland with a high degree of production specialization has larger area of field, less kind of crops, higher yield of crop and more input, while farmland with complex landscape has lower yield, higher biodiversity and less input. So they thought that the idea that simple landscape structure was good to improve the intensity of land use may be misleading (Roschewitz et al., 2005). And many countries take farmland corridor as an important part of rural cultural heritage and protect it to enhance the tourism value of rural landscape.

Farmland use in China is mainly in the form of plot. What are considered is confined in the inside plot. Even though external conditions are considered, they are mainly connected with essential infrastructure related to direction of land use, and it is hard to take the harmony of regional rural landscape. Different places have their unique landscape and culture, which forms rural landscapes with different characteristics. At present, farmland consolidation in the purpose of intensive operation in China is difficult to break existing pattern, which caused landscape machine-made. Precision farmland consolidation project should not only meet the demands of precision agriculture but also pay attention to protecting local traditional landscape, and highlight the specialty of local landscape and reflect local cultural connotation.

5. CONCLUSIONS

Precision agriculture based on agricultural mechanization and 3S technology, which integrates modern electronic information technology, decision-making support for crop cultivation management and agricultural engineering equipment technology, has been recognized as the most advanced agricultural technology in the 21st century, which is being demonstrated and promoted globally by the leading of the USA. In 1994, Chinese scientists started to care about precision agriculture. But restricted by conditions, precision agriculture was not paid much attention to until the beginning of the 21st century and included in 863 national schemes. Meanwhile, demonstration zones were established in Beijing and Heilongjiang (Sui Changling et al., 2005). At present, precision agriculture is in the stage of experiment, demonstration and development. Compared with developed countries, there is still a large gap on technology level, operation management and economic benefit. It is necessary not only to break through technology but also to create production conditions. Therefore, it's an inevitable developing trend of agriculture in China to change the style of petty-farmer management, to turn decentralized management to centralized management gradually, to rebuild farmland landscape pattern constantly on scale and shape of cultivated field, farmland production facilities and farmland matrix in order to adapt to the requirements of future development of precision agriculture.

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APPLICATION OF GIS COMBINING WITH LIMITS OF VORONOI DIAGRAM IN SOCIOECONOMIC FACTOR OF AGRICULTURAL LAND GRADING

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Abstract: As regards the influencing radius and influencing area of agricultural land grading factor, the agricultural land grading regulation simply use decay method or exponential method to determine their values, what is more, it only considers the natural factors of land grading and takes little account of socioeconomic factors. So, there are some defects in agricultural land grading. To address above issues, this paper purposes the limits of Voronoi diagram method to determine the influencing radius and influencing area of agricultural land socioeconomic factors to overcome these deficiencies, besides, verifies its feasibility combining with GIS in theory.

Key words: limits of Voronoi diagram, agricultural land grading, GIS

1. INTRODUCTION

Agriculture land grading is an overall evaluation for present agricultural land and unused agricultural land in county-level districts according to their natural, economic and social conditions. In order to carry out Chinese agricultural land grading policy, some researchers have implemented

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comprehensive research work, especially the development of GIS in land grading. GIS is a computer system which can import, store, process spatial data and connect attribute data with spatial data, besides, it is convenient for managing and analyzing land information. GIS will play an important role in agricultural land grading and increase efficiency. Some Chinese researchers have made certain achievements in land grading system based on GIS by now.

In theoretical research, agricultural land grading methods based on GIS mainly involve with the database creation, the method and comparison of defining grading units (Lingchao Wang et al., 1999; Junguo Liao et al., 2001). On the basis of these, application of GIS spatial analyzing functions is another research area (Qigang Zhou et al., 2006). Agricultural land grading based on GIS is essentially the process of developing a software, it ranges over every detail in system development, hence, the agricultural land grading combining with GIS theory is priority research areas (Shaoshan, Li et al. 2002; Jianxin, Lin et al. 2002; Yong, Zhou et al. 2002).

From this, it can be seen that applying GIS in agricultural land grading has mainly played a role in database management, spatial analysis and decision support. The main technical points for using GIS in land grading are the foundation of basic map database, attribute database and defining grading factors and models.

2. VORONOI DIAGRAM

At first, this paper will put emphasis on application of Voronoi diagram in agricultural land grading before introducing limits of Voronoi diagram.

Voronoi diagram is a data structure which describes spatial adjacent relations, it was proposed by Russian mathematician Voronoi in 1908 at the earliest. In other fields, Voronoi diagram is also called Thiesesn polygon, Dirichrit grid, Wigner-Seitz region, centre shaft, internal skeleton and so on. The wide use of Voronoi diagram in practice has great developed in the last thirty years, its research and application areas involve the processing of geometry bodies reconstructing graphic image and pattern recognition, physicochemical molecular biology, robot movement planning, processing of path planning and so on (Yongqiang Du, 2005).

Voronoi diagram is originally defined for point-group which divides a plane surface into a number of regional planes, each point corresponds to one region. Besides, each region is composed of the points which are nearer than others in set. That is, set $S = \{P_1, P_2, \dots, P_n\} \in E^2$ as the N-point collection on the plane, P_i, P_j are any two points and $i \neq j$, hence, define

$V(P_i) = \bigcap H(P_i, P_j)$ as Voronoi diagram which P_i matches along with and then it must meet the requirement

$$V(P_i) = \{P \in E2 \mid P - P_i \leq P - P_j, i \neq j, i = 1, 2, 3, \dots, n\} \quad , \quad \text{the}$$

Voronoi diagram of S ($\text{Vor}(S)$) is defined as a union of all Voronoi polygons which every points corresponding to, so, $\text{Vor}(S) = \bigcup (P_i)$. That is to say, Voronoi diagram on plane can be regarded as that every point in S is an organic centre which expands its area at the same speed until they meet and the graph is formed (Lina Chen et al., 2007). Here is a Voronoi diagram generated by points:

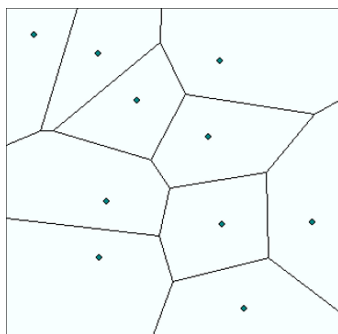


Fig.1: Voronoi diagram generated by point factors

3. SOCIOECONOMIC FACTORS OF AGRICULTURAL LAND GRADING

3.1 An overview about grading units of agricultural land socioeconomic factors

According to natural conditions such as the distribution of farmland, geomorphic type and property of soil, the main methods of dividing grading units of agricultural land are overlay method, land parcel method, grid method and polygon method. However, these methods are based on natural factors. Under certain conditions, socioeconomic factors also have effects on agricultural grading, for this reason, it is necessary to consider social influence, anyway, the effects between natural and socioeconomic factors is entirely different, so, it is inappropriate to use classification methods of natural factors on socioeconomic factors while dividing grading units. Because agricultural land grading regulations have not got involved in the

division of grading units of agricultural land socioeconomic factors, this paper applies Voronoi diagram in it in order to overcome these shortcomings.

3.2 The division of socioeconomic grading units of agricultural land

As shown in Fig.1, we can see that Voronoi diagram is composed of multi-polygons, if we regard the rectangle in Fig.1 as a farmland, every point as a socioeconomic factor, so that the polygon is a region which the corresponding point affects on, in other words, the polygon is a socioeconomic unit. Therefore, the division process has been done. This method is under the conditions that every factor is same and the division only has connection with the distance among factors, it is a perfect state. Here are the feasibilities about this method.

1. Voronoi diagram represents the geometric spatial arrangement, the irregular spatial distribution of socioeconomic factors (e.g. central city, farmer's market, warehouse, road capacity) are extremely similar to the points' distribution within Voronoi diagram;

2. Each polygon of Voronoi diagram can be regarded as the grading unit of socioeconomic factors;

Here are the concrete steps of applying Voronoi diagram in the division of agricultural land grading units according to socioeconomic factors:

1. Determine the grading factors;

2. Attribute grading factors to points, lines and polygons according to the research area scale;

3. Generate Voronoi diagram based on points, lines and polygons as centers separately, the polygons within Voronoi diagram are the grading units (if there is grade differential, use weighted Voronoi diagram (Yu Pang et al., 2007) to divide grading units).

Compared with the methods of agricultural land grading regulations, the division of grading units of agricultural land socioeconomic factors based on Voronoi diagram has no limits of conditions, such as present land-use map, soil map and so on, this method divides socioeconomic grading units of farmland is more scientific and reasonable.

3.3 The influencing radius of agricultural land socioeconomic factors

The traditional influencing patterns of land grading factors can be classified into points, lines and polygons. For points, the agricultural land grading defines them as concentric circles diffusivity factors. The formula of influencing radius is:

$$R = (S / n\pi)^{1/2} \quad (1)$$

Where: R is the influencing radius of agricultural land grading (m), S is the influencing area of grading factor (m^2); unit: square meter; n is the number of grading factors. $R = S / 2L$

For lines, the formula is:

$$R = S / 2L \quad (2)$$

Where: L is the length of grading factors (m).

The above formulas are defined under the assumable conditions that the research area is regular, but the influencing radius will decrease if the research area is irregular or there are barriers such as rivers, railways in the area (Yongqiang Du, 2005). Therefore, it is necessary to improve these formulas.

In regard to the problem, Voronoi diagram can play its unique advantages, especially under the circumstances of the irregular shape of research regions, the grading factors are uneven distribution. For this reason, some researchers have applied Voronoi diagram in land grading.

In urban land grading, Voronoi diagram can define the influencing radius of grading factors and this method is more accurate than traditional methods (Shiyuan Hu et al., 2004, 2006). Jianhua Zhu (2005) used Voronoi diagram in trade estate grading, he regards every Voronoi polygon as an assessment classification unit, completed the trade estate division, in addition, defined the influencing area of each business center. So, it is clear that Voronoi diagram can help to finish land grading and play a good role in it.

3.4 The influencing radius of agricultural land using Voronoi diagram

Because of the uneven distribution of farmland grading factors in reality, we can take the advantage of Voronoi diagram to define the influencing radius of grading factors more scientific and reasonable.

The polygons of Voronoi diagram are close, hence, we can regard them as the units of grading factors, the maximum distance from grading factor to its corresponding polygon is the influencing radius of grading factor and the polygon's area is the influencing area of grading factor. It is practical to generate Voronoi diagram according to the grading factors' shape, and compute the influencing radius.

In the process of agricultural land grading, we can make use of GIS software or programming languages to generate varied Voronoi diagrams. In the diagram, each polygon is the corresponding influencing area of grading factor and its radius is the influencing radius of grading factor. As to cross-impact factor, generate Voronoi diagram of each factor separately on its

layer firstly, then, overlay these layers and compute their influencing radius by weighted method.

3.5 The application of limits of Voronoi diagram in agricultural land

The above Voronoi diagrams are generated under no interruptive and limit conditions, however, it is an ideal status. Although the method is simple, the practical situations are not well considered, that is to say, it takes no account of natural or man-made constrains, so, the grading unit and influencing radius will be incorrect in such a case. In order to define the socioeconomic grading units and influencing radius of agricultural land more reasonable, Voronoi is a better way.

Limits of Voronoi diagram can be defined as:

In the Euclidean plain, set $S = \{P_1, P_2, \dots, P_n\}$ as original generator points set, $R = \{Q_1, Q_2, \dots, Q_m\}$ as noncrossing any shape of geometry set,

use $R(S, P_i) = \bigcap_{i \neq j} \{P \mid O(P, P_i) < O(P, P_j)\} (i = 1, 2, \dots, n)$ to segment

the plane, the segmented regions are called generator based on $P_i (i = 1, 2, \dots, n)$. $Q_i (i = 1, 2, \dots, m)$ is called limits of Voronoi diagram (Qingjie Cao, 2007). Fig.2 shows the limits of Voronoi diagram:

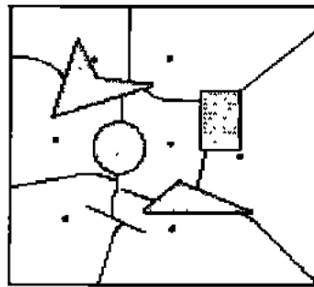


Fig.2: Voronoi diagram with obstacles

In the situation that there are obstacles among grading factors (e.g. a river separates two farmer's markets, shown as Fig.3), limits of Voronoi diagram can solve this problem.

As shown in Fig.3, A,B,C,D are farmer's markets, the rectangle is a farmland, the area between blue lines is a river. The graph has divided grading units (influencing area) by Voronoi diagram based on A,B,C,D, if there was no river, the polygons which A,B,C,D corresponding to are the grading units for every farmer's market, the polygon's radiuses are the influencing radiuses. A is in farmland, once there has business deal, A

should be the first selection. However, the river is an obstacle between the markets which causes inconveniences, so that if we still chose A, it will no longer a good choice. In such case, in order to get reasonable grading units and influencing radius, it is necessary to consider the river, afterwards, divide the units by Voronoi diagram that will generate new grading units and influencing radius. Hence, in the condition of obstructive factors, the agricultural land grading work should consider these limits in accordance with the objective disciplines and divide the research area using limits of Voronoi diagram, thereby, define the grading units and influencing radius.

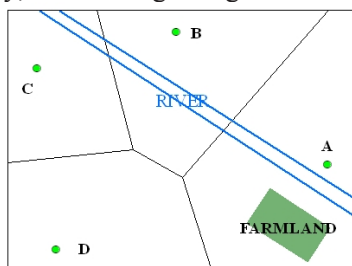


Fig.3: Sketch of obstacle factors

4. AGRICULTURAL LAND GRADING BASED ON GIS COMBINING WITH LIMITS OF VORONOI DIAGRAM

GIS has the capacity of inputting, storing, processing, managing, analyzing and outputting spatial data, the agricultural land grading based on GIS is a new field of application. GIS can manage farmland's spatial and attribute data effectively, in addition, process, analyze these data and finish farmland classification finally. Whether the grading results are accurate or not mainly rely on the algorithms' reasonableness. For the confirmation of grading unit and influencing radius, applying limits of Voronoi diagram in agricultural land grading can optimize traditional algorithms and get more scientific and reasonable results.

The existing GIS software such as ARCINFO, MAPGIS all have the function of generating Voronoi diagram. The limits of Voronoi diagram can be generated by secondary development based on GIS, therefore, it is feasible to use limits of Voronoi diagram in agricultural land grading. The application of GIS's spatial analysis functions and limits of Voronoi diagram in agricultural land grading will compute and analyze the influencing radius and area of farmland grading factors better, what is more, can also help to locate and program the grading factor (Jun Lu et al., 2003).

5. CONCLUSION

At present, there are some defects in agricultural land grading regulation, for this reason, this paper applies limits of Voronoi diagram in the division of grading unit and influencing radius of agricultural land grading, proposes the method of generating limits of Voronoi diagram in agricultural land grading according to practical and obstructive conditions, verifies this method's feasibility and reasonableness in theory.

Chinese researchers have developed some agricultural land grading systems based on GIS and apply it in practical work, so, after improving the theory of agricultural land grading, based on GIS will play a better role in agricultural land grading.

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EFFECTS OF LUCC RESULTING FROM TFFP LAND USE PATTERN IN THE YELLOW RIVER DELTA, CHINA

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Abstract: This paper traces the environmental and economic effects of a “Table field—Fish pond” (TFFP) land use scheme in Lijin County in the Yellow River Delta of China with reference to the optimization of ecological-productive structures resulting from a land use / land cover change (LUCC) approach. “Table field-Fish pond” is an effective reconstructed land use system and eco-agricultural pattern to change low-lying saline land and fragile eco-environment. As an important human initiative, the LUCC at regional scale promote sustainable land use, promote eco-environmental improvement, provide productive structural regulation, and support sustainable economic development practices.

Keywords: land use / land cover change (LUCC); effect; “Table field-Fish pond” (TFFP) land use pattern; Yellow River Delta; China

1. INTRODUCTION

Land use / land cover change (LUCC) is one of the more significant issues between physical and human processes, embodying the essence of human-

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land relations (Ingram J. & Matson P. 1998; Physical Geographical Committee, 1999). LUCC has been designated as a core field of study by the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP), and has therefore received great attention from scholar worldwide (Turner *et al.*, 1995; Li, 1996; IGBP, IHDP & WCRP, 2001). In trying to better understand LUCC issues, researchers should give some attention to qualitative changes within the soil matrix as well as the ecological effects of such changes in addition to the attention already given to dynamic interactions and driving force analysis of quantitative changes (Leng and Li, 1999; Guo *et al.*, 2001; Xu *et al.*, 2001). There is also need for additional study at a variety of scales on relations between LUCC and other issues such as global environmental change, regional sustainable development, and local ecological improvements and the mechanisms necessary for their implementation. The purpose of this research is to use the LUCC approach to examine the environmental, economic and social effects of the “Table field—Fish pond” land use reconstruction patterns on the saline lands of the Yellow River Delta, China, as well as discuss regional structural optimization of ecological-production resulting from LUCC.

The study region is Lijin County in the Yellow River Delta where is one of the new developing regions in China with great potential in resources, but a rather frail ecological environment. It is also an important national agricultural production base. Within this region, there is a large stretch of land that has yet to be exploited due to a number of restrictive factors; such as shallow heavy mineralized ground water levels, salinized soils, frequent droughts, and limited fresh water supplies due to interruption in the Yellow River flow during low flow seasons. In overcoming these conditions, local farmers created the “Table field—Fish pond” (TFFP) land use system; locally known as “farming up-fishing down.”

The TFFP system involves digging deep ponds to breed fish and using the burden from the ponds to build high table-fields for cultivating crops. The system has been practiced in the Yellow River delta region and in other low-lying saline belts. The table-fields drop the groundwater level relatively speaking, while the saline lands are transformed using fresh water to rinse and remove the salt. As practiced, the “farming up-fishing down” approach is a tri-dimensional cultivation system used to increase the efficiency of land use. At regional scale, the land use and land cover changes result in a series of changes in ecological environment and economy.

2. STUDY METHODS

We use the methods combining natural and human sciences, which including:

(1) On the basis of analyzing the structure of the TFFP land use pattern, we calculate the areas of land use types before implementing TFFP (1991) and after popularizing TFFP (1998) in Lijin County to understand the land use and land cover changes at regional scale.

(2) To review the ecological effects of the TFFP land use pattern, soil samples from reconstructed table fields and nearby original saline lands, as checking points, were collected and tested. At each location, soil was collected from a profile of 0-30cm in depth, taken samples at surface, 10cm and 30cm respectively; 3 pieces of soil were picked and then mixed into one single sample. Because the level of salinization and the organic content are the key indicators of land quality in the Yellow River Delta region, our soil analysis focuses on these two indicators. The level of salinization was measured by testing the conductance of the salt contents in soil solution; the organic content was measured using the method of potassium dichromate. We also analysed other ecological effects of TFFP at regional scale.

(3) In fact, TFFP land use pattern is an eco-agricultural scheme. The LUCC bring the changes of production structure. We compare the structure of product value in Lijin County in 1991 to those in 2005 to show productive structural regulation. And farther more, we design a perfect eco-agricultural model of “table filed-fish pond”.

(4) By means of investigation and calculate the gross output value of agriculture (including farming, forestry, animal husbandry and fishery) in Lijin County and Chenzhuang Town, a demonstration district of TFFP, at the end of different years, so as to know the economic and social effects of TFFP contributing to local economic development. At a TFFP unit scale, input-output analysis is applied to evaluate the economic income based on the peasant household survey.

3. RESULT ANALYSIS

3.1 Basic structure of TFFP land use pattern and regional LUCC

The typical TFFP land use system has a structure of “442” framework, where the area of the pond, table field, and road and ditch zone occupies

40%, 40%, and 20% of the overall area respectively. Because the threshold value restricting the rise of salt content in the local sandy soil in the area is about 1.5m, the table field must be no less than 2m. The normal structure of the pattern is shown as Figure 1.

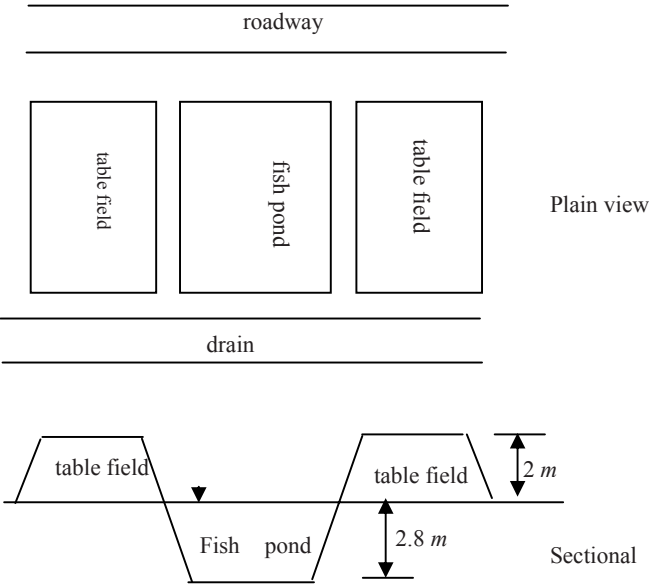


Fig 1: Basic structure of “Table field –fish pond” land use pattern

Table 1. Area changes of land use / cover in Lijin County

Year	1991	1998
Farmland	57291	53051
Garden	368	1406
Woodland	1833	1575
Grassland	2603	2137
Settlement & industrial land	9330	10620
Traffic land	1826	2217
Water area	28694	32573
In which: pond	2981	3734
Unused land	26696	25112
In which: wasteland	3541	2751
Saline	22718	21791
Total area	128691	128691

Source of data: the land management Bureau of Shandong Province, China

At regional scale, popularizing TFFP land use pattern has resulted in land use and land cover changes. Table 1 presents the findings from a comparison

of land use/land cover in Lijin county in 1991 (without the TFFP system) to the same area in 1998 with the TFFP system in use. Several obvious changes can be seen relative to the development of TFFP system, especially the reduction in waste and saline lands, and the increase in ponds and freshwater agriculture.

3.2 LUCC and ecological effects

We checked many reconstructed fields’ effects by soil samples. For one example, Table 2 presents the results for soil samples collected in a field managed by Mr. Jiabing Guo, a common farmer.

Table 2. Testing results of soil samples for “Table field – Fish pond” effects

Mark of samples	Depth	Organic matter(%)	Salt content (%)	Remark
L ₁ -1	Surface soil	0.983	0.058	Table field, vegetable
L ₁ -2	10cm	0.571	0.650	
L ₁ -3	30cm	0.790	0.340	
L ₂ -1	Surface soil	0.570	0.890	Table field, reed
L ₂ -2	10cm	0.695	2.060	
L ₂ -3	30cm	0.320	0.790	
L ₃ -1	Surface soil	1.020	2.030	Saline (checking point to L ₁ , L ₂)
L ₃ -2	10cm	0.530	2.410	
L ₃ -3	30cm	1.200	0.270	
L ₄ -1	Surface soil	0.517	0.046	Table field, maize & bean
L ₄ -2	10cm	0.220	0.048	
L ₄ -3	30cm	0.230	0.067	
L ₅ -1	Surface soil	0.580	2.600	wasteland (checking point to L ₄)
L ₅ -2	10cm	0.290	1.220	
L ₅ -3	30cm	0.600	0.750	

A comparison of points in the original saline lands with table fields indicates that the saline content has decreased as well as the amount of organic matter. The TFFP pattern has effectively changed the major restrictive factor - too much saline in the original land. During the initial stages, however, soil organic matter may decrease because the original topsoil is often covered by new soil when digging the ponds and building the table fields. Interviews with local farmers helped clarify the observed differences among the three samples L₁, L₂, and L₃. L₁ and L₂ came from different plots in the same table field. The crops from this field did not grow well because the soil was poorly ventilated as the field was built by slurry pumping and deposition four years earlier. Site L₁ is in a vegetable plot where salinity had decreased and organic matter accumulated because of intensive cultivation. L₂ was a barren uncultivated plot, whose salinity was

reduced in the surface soil because of eluviation from rainwater. The table field with sample L₄ was built one year before by an excavator. The soil is ventilated and maize, soybeans and asparagus are intercropped and growing well.

Besides improving saline soils, the TFFP land use pattern has other ecological effects. Because the ponds coexist with table fields, they serve as small reservoirs. Because they store fresh water, they are able to supply the necessary cultivation water in dry seasons or when the Yellow River flow is interrupted. For example, in 1997 and 1998, there was a severe drought and the ordinary farmlands all decreased in output. Table lands, on the other hand, all had good harvests in addition to the output from fishing in the ponds. The TFFP system is able to serve as a sustainable land use pattern through consistent yields because it provides irrigation during drought and draining when waterlogged. In addition, the local microclimate has higher relative humidity levels because of the added moisture from the ponds.

3.3 LUCC and regulation in the structure of production

The application of LUCC analysis to the TFFP pattern has led to changes in the structure of production. The comparison of product value shares for the farming, forestry, animal husbandry and fishery industries in Lijin County in 1991 to those in 2005 are presented in Figure 2.

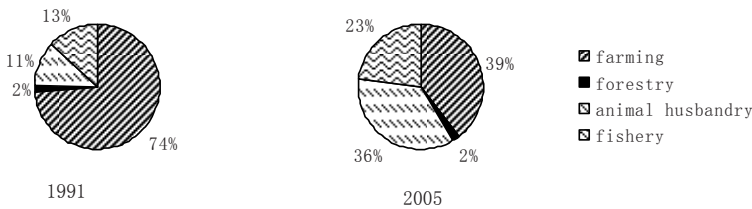


Fig. 2: Agricultural productive structure from 1991 to 2005 in Lijin County (Source of data: The Statistics Bureau of Lijin County.(1991) Statistical data in Lijin county;The Statistics Bureau of Lijin County.(2006) Lijin Statistical Yearbook.)

Naturally, the changes identified above are related to agricultural policy, but the development of fishery sector is a direct benefit of the new land use pattern. In 1991, fresh water agriculture occupied only 5.92% of the fishery product share, but increased to 33.71% in 2005 as a result of the TFFP land

use system. The TFFP system has changed both the regional land use structure and pattern of production as the areas devoted to agricultural have increased from 533ha in 1991 to 4667ha in 2005. As the useable land increase, more areas can be used for animal husbandry to gain higher benefits instead of simplex used for farming. Thus, agricultural productive structure has changed in the whole county.

3.4 LUCC and economic and social effects

(1) Economic effects

Figure 3 shows the changes of gross output value of agriculture in Lijin County:

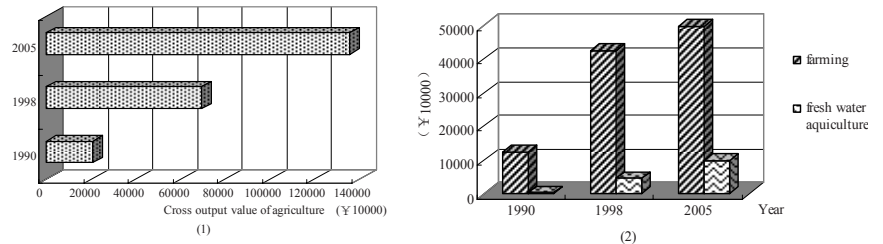


Fig. 3: Rise of the gross output value of agriculture (1) and output value of farming and fresh water aquiculture (2) in Lijin county (at the 1990's constant price)

The gross output value of agriculture has increased from ¥206.92 million *RMB* in 1990 to ¥2224.48 million *RMB* in 2005 (¥1354.56 million *RMB* in constant *RMB* terms). Moreover, related to TFFP, the output value of farming in 2005 is 4.05 times greater than that in 1990, and the output value of fresh water aquiculture in 2005 had reached 38.96 times as much as that in 1990 (at the 1990's constant price). In Chenzhuang Town, a demonstration district utilizing the “farming up-fishing down” pattern, 1990 gross output from agriculture value was ¥7.22 million *RMB* without a fresh water agriculture component. In 2005 agricultural output reached ¥242.36 million *RMB*, including ¥48.36 million *RMB* (in 1990's constant *RMB* terms) from fresh water fisheries. The change on the gross output value and structure of farming, forestry, animal husbandry and fishery in Chenzhuang Town are shown in Figure 4.

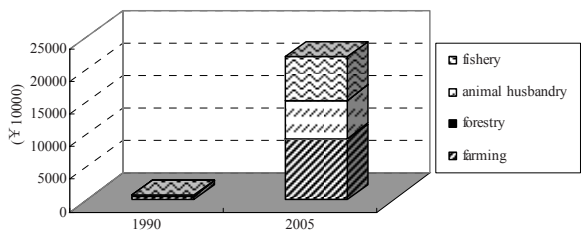


Fig. 4: Changes in the gross output value and structure of agriculture (including farming, forestry, animal husbandry and fishery) in Chenzhuang Town in Lijin county(at the 1990's constant price)

In 1998, the gross domestic product value from all sources in Chengzhuang Town was ¥1.25 billion *RMB*, with the area devoted to TFFP amounting to 10,000*mu* (667ha) and gross aquatic output reaching 1,040,000 kg. Primary products from the TFFP system included asparagus, earthnut, grape, melon and vegetables, whose total production was ¥19 million *RMB* with a net profit of ¥8.9 million *RMB*. On a per farmer basis, net income was 4.7 times greater than in 1990.

According to the peasant household survey, averagely a peasant household with 3 or 4 members can gain about ¥ 107850 *RMB* income from a “442” TFFP unit (plant cotton in the table field). The ratio of output to input is 1.92 for the total unit. Respectively, the ratio of output to input of table field (2.80) is higher than that of fish pond (1.78). The engineering cost of a “442” TFFP unit is about ¥ 81000 *RMB*, which means the investment can be recouped in one year. At present, the “cotton field-fish pond” agricultural pattern becomes one of the most popular production modes. The detailed input-output data is shown in Table 3.

Table 3. The currency input-output of a “442” TFFP unit in 2006

Cotton field			Fish pond	
	Items	Value (RMB)	Items	Value (RMB)
Input	Cotton seed	750	Fry	15000
	Soil fertilizer	6000	Feed	19500
	Irrigative water	450	Water fertilizer	10500
	Agricultural machinery	1200	Pond water	15000
	Plastic film	750	Electricity charge	1500
	Electricity charge	300	Medication	5100
	Pesticide	600	Labour force	10500
	Transport cost	3000	Transport cost	18000
	Others	3000	Others	6000
	Total	16050	Total	101100
Output	Cotton	45000	Fish	180000
Income	28950		78900	

(2) Social effects

Meanwhile, the exploitation of the “farming up-fishing down” pattern has also brought out good social effects. For instance, in Chenzhuang Town, the local government established the developing policy and mechanism: “make uniform planning, exploit wasteland piece by piece, reconstruct table land to transform soil salinity, combine fishery with farming” and “service from the government, management by village committee, operation by contractor”. That is, the government unifies the criteria and constructs the basic establishments such as production roads, culverts and water gates, pumping stations, and also spread new techniques.

Because the TFFP agricultural pattern effectively improved the low-lying soil quality and created much benefit for local residents, large area of saline land was exploited. The demand of labor force provided many employment opportunities for rural idle labors. At the same time, some youth labors who flowed to developed regions was attracted back to their hometown. Because the government has really served for farmers, the prestige of the government has advanced, and also has brought a closer relation between the governors and the masses.

4. DISCUSSION

While the TFFP system of land use has seen significant increases in production and economic value where applied, there are difficulties. The TFFP approach must find solutions to the following issues: (1) the marginal slope of the table field is apt to collapse, (2) table fields built by means of pumping and depositing with a slurry pump are slow to mature because of bad ventilation in the soil, (3) changing saline land into a “Table field—Fish pond” system has a high initial cost, making it difficult to implement without the support of government., and (4) the impact increasing output might put on driving prices lower.

In view of the above problems, several relevant countermeasures might be adopted: (1) cover vegetation over the marginal slope of table field to control collapse and soil erosion, (2) build table fields using an excavator; if pumping and depositing method are used, implement deep ploughing and intensive cultivation, (3) explore the capital circulation mechanism for exploiting waste lands with a view toward collecting, regulating and reclaiming the capital, and (4) according to the different periods of desalinization, cultivate different crops or other plants in the table fields and implement intercropping and inter-planting.

5. CONCLUSION

The analysis of the effects of land use and land cover changes resulting from the development of the “Table field—Fish pond” land use pattern has led to the following conclusions:

(1) “Table field-Fish pond” is an effective land use system and eco-agricultural pattern to change low-lying saline land use structure while sustaining the fragile ecological environment.

(2) Large-area development of the “Table field—Fish pond” land use pattern has led to a regional LUCC approach and a series of ecological, economic, and social effects resulting in a more efficient regulation and optimization of the structure of production.

(3) Through human initiatives, LUCC studies help advance sustainable land use, improve the ecological environment, provide regulation and optimization in the regional structure of ecological-production, and support sustainable economic development.

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*Effects of LUCC Resulting from TFFP Land Use Pattern in the Yellow441
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DEFINITION OF MANAGEMENT ZONES OF SOIL NUTRIENTS BASED ON FCM ALGORITHM IN OASIS FIELD

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Abstract: The objective of this research was to define management zones of oasis cotton field. The variables of organic matter, available N, available P and available K data determined in 193 topsoil (0-30cm) samples were selected as data sources. Fuzzy c-means clustering algorithm was used to delineate management zones. In order to determine the optimum fuzzy control parameters, the fuzziness performance index (FPI), c-φ combinations and the multiple regression based on external variable were used in this study. Meanwhile, the cotton yield was chosen as the external variable. The whole field was divided in four management zones. And fuzziness exponent was 1.6. The zoning statistics showed that variation coefficient of soil nutrients decreased, while the means of the soil nutrients differed sharply between management zones. The average confusion index was 0.19 in all management zones. The overlapping of fuzzy classes at points was low and the spatial distribution of membership grades was unambiguous. The results indicated that fuzzy c-means clustering algorithm could be used to delineate management zones by selecting the appropriate external variables. The defined management zones can be used for fertilizer recommendation to manage soil nutrient more efficiently.

Key words: Management zones; Fuzzy clustering; Soil Nutrients, external variables, Oasis cotton field

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1. INTRODUCTION

Study on the precise management zone in the basis of multi-type soil characters in the inner-land oasis, not only can master the oasis agriculture ecological environment feature and the special production function, but also is very important for reasonable development and sustainable development of the oasis agriculture. With regards to the soil characters variance, the management that cut the whole area into the different mean texture zones was become a focus spot in the precise agriculture (Schepers et al, 2004). The fuzzy c-mean algorithm (FCM) was most widely used in the management zones. But FCM method exists fuzzy control parameter (fuzzy type number and fuzzy weighting exponent) can not be easily determine; the analyze ability is worse for the factors in the different kinds of boundaries (Shi Hongbo et al, 2003). They have been become the continuous explore theme. De Bruin (1998) stated the multi-fitting methods on the basis of extraneous vary. The method didn't obtain the information from the algorithm method, but determine the reasonable fuzzy control parameter by analysis of the extraneous vary and spatial distribution relation of subordination degree for fuzzy data collection. The paper researches the big farmland in the inner-land oasis agriculture mode, use the multi-kind of soil character as the data resource, and apply the fuzzy *c*-mean classification method to define the field management zones. On the basis of inform study, making the cotton yield as the extraneous vary. At the same time adopted the no-determine complex degree of the fuzzy subordination relationship with confusion index (CI) surface sample to assessment to the feasible for the management zone for the big field in the northern oasis agriculture mode.

2. MATERIAL AND METHOD

2.1 Research Area Survey

The experiment region was No.148 region of Xinjiang production construction army-group. It lies in the 44°46'50"-44°59'25"N, 86°9'10"-86°22'51"E. The climate belongs to the continental climate, the rainfall is rare, and the resources of light and heat are very rich. The topography is smooth, besides the fluctuation partially; there are mainly gray desert soil, Aeolian sandy soil and salt soil, in the total the five second-type and nine soil families. The crop in the region mainly plant cotton, the cultivated area is 12,800ha, the agriculture management lacks of central management, the quantity fertilizer including extra fertilizer is the same in the block.

2.2 Soil data obtain and sample analysis

In October ,2006, we collected the soil sample according to the no-regular way in the 148 region drip irrigation zone, the sample centralization on the each sample spot was the centralization of circular, radius was 4.5m. at the depth of 0-30cm in the soil main cultivate in the range of circular collected five soil sample and combined, the sum of soil sample was 193. At the same time, measure the yield in the range that was length of 5.86m, width of 2.25m, is the centralization on the basis of the soil sample. The field of cotton is the output in the ha unit area. The soil sample collected became dry in the air and need to sieve out the stones from the soil, and then measured in the lab. The projects of each soil sample include the OM, AN, AP, AK and total salt. (Bao Shidan, 2000).

2.3 Fuzzy classification and interpolation

Fuzzy *c*-mean algorithm is a no-surveillance algorithm method, which is widely used in the classification of soil, topography, terrain features, output and remote data. For multi-resource of a spatial sample number n , soil character number p , fuzzy *c*-mean algorithm can determine the reasonable fuzzy type number c , define the algorithm centre and computer the fuzzy subordination for each classification class.

The basic idea is make iterated objective function become minimized; the function was used as following:

$$J(MC) = \sum_{i=1}^n \sum_{j=1}^c \mu_{ij}^{\varphi} d_{ij}^2 \quad i = 1, \dots, n; \quad j = 1, \dots, c \quad (1)$$

In the middle of equation (1), C is algorithm type centroid matrix $c \times p$, M is sample fuzzy subordination degree matrix $n \times c$, $\mu_{ij} (\mu_{ij} \in [0,1])$ is the j algorithm type subordination degree number to the soil character for the i sample spot, $\varphi (\varphi \geq 1)$ is a control algorithm result and type overlapping degree constant factor (Gao Xinbo et al, 2000), also is the fuzzy lighting exponent, d_{ij}^2 is the distance square between the i soil sample spot character and the j type centre.

Outside standard analysis is built on the basis of extraneous vary; which is not use the algorithm analysis, but is impacted by the outside condition impacted the algorithm. For the outside standard analysis, if the stronger relationship between the spatial variance of extraneous varies and the spatial distribution of spatial subordination degree of soil nutrient, the fuzzy *c*-mean algorithm can better express the effect of the soil data algorithm. The multi-fitting method built by de Bruin and Stein computed the relationship

between fuzzy subordination degree and extraneous vary. The fitting model of fuzzy subordination degree and extraneous vary shows in the equation (2). In the equation (2), β_0 、 β_1 、... β_c are the fitting coefficients, ε is random error, the check decision coefficient r_a^2 in the fitting model can express the relation between the different c value and φ , when r_a^2 is in the peak, the c value and φ is most best reasonable. In the middle of equation (3), r^2 is the decision coefficient in the fitting equation, n_s is the sample number of extraneous vary.

$$\text{Extraneous vary} = \beta_0 + \beta_1 \mu A_1(x) + \dots + \beta_c \mu A_c(x) + \varepsilon \quad (2)$$

$$r_a^2 = r^2 - \frac{c(1-r^2)}{n_s - c - 1} \quad (3)$$

In the study, extraneous vary is the cotton yield data in 2006 year according to the result as following.

In the basis of algorithm class result, make the partially subordination relationship of the different soil nutrient content for the sample soil normal kriging method and get the sole category fuzzy chart for soil nutrient. At the same time, in order to determine the overlapping degree between the sample spot for the different soil character type, use the confusion index to estimate the fuzzy no-determine for the soil sample subordination relationship (Burrough et al, 1997).

$$CI = 1 - [\mu_{\max i} - \mu_{(\max-1)i}] \quad (4)$$

In the equation (4), $\mu_{\max i}$ is the biggest subordination degree value for the certain soil type character for the i soil sample spot, $\mu_{(\max-1)i}$ is the second subordination degree for the soil subordination relationship.

In the study, Fuzzy c-mean algorithm is successfully used by software MATLAB7.0; the variance feature analysis of fuzzy subordination degree, semi-variance function computing, theory model fitting, kriging method and chart drawing are both completely made by the software of GS+3.5 and ArcGIS9.2.

3. RESULTS AND ANALYSIS

3.1 Descriptive statistics results

Descriptive statistics of soil nutrient and cotton yield in the research region (Tab.1), recognition check of data in the data value domain does not

exist the outlier. From the mean value, according to the Xinjiang soil survey management (Xinjiang Production and Construction Corps Soil Survey Office, 1993), in the research region, the content of organize material (OM) and available phosphorus belongs to the middle level, the content of available nitrogen is lower than middle level, the content of available potassium is richer. According to the vary number CV, the variance degree can be roughly estimated, the results are made as following: the weak variance of CV is smaller than 10%; middle variance of CV is lie in the range of 10 ~ 100 % ; Strong variance of CV is bigger 100 % (Wang Shaoqiang et al, 2001), in the research zone, soil nutrient was impacted by large-scale mechanization of agriculture work and personal factor under membrane drip for long years, the middle variance is still showed the soil spatial character in the zones and can satisfied with agriculture management zone divided and the prerequisite condition to vary fertilized management.

Tab.1: Descriptive statistics of soil properties and cotton yield

Soil properties	Min	Max	Mean	SD	CV(%)
OM(g/kg)	3.80	22.50	10.37	2.92	28.18
AN(mg/kg)	20.00	102.00	47.63	12.85	26.98
AP(mg/kg)	3.60	40.60	12.29	5.66	46.03
AK(mg/kg)	161.00	519.33	318.02	58.26	18.32
Cotton yield(kg/ha)	1297.42	2925.15	1970.18	374.49	19.00

3.2 Fuzzy classification result output of soil nutrient

Bring the soil nutrient fuzzy collection $n \times p(n=193, p=4)$ into fuzzy c-mean method and make fuzzy algorithm on the basis of the related method above.

Adopted multi-fitting method on basis of extraneous varies to determine the reasonable fuzzy control parameter. The result of method permits simultaneously choice c and φ , it is same with c - φ multi-combination. Take the cotton yield dada in 2006 in the research region extraneous vary to compute the fitting model between the yield and the fuzzy subordination degree of the different c and φ , the change relationship between the adjusted coefficient of model and φ shows in Fig 1. We can get the result, r_a^2 is more and more when φ is more and more, r_a^2 reaches peak value 0.57 when $c=4$ 、 $\varphi=1.6$.

Fuzzy control parameter determined are $c=4$ 、 $\varphi=1.6$, the whole region is divided into four soil nutrient management zones, class centroids of soil properties and Partial memberships and confusion index of the sampled soils to the classes shows in the Tab.2 and Tab.3. In order to examine the over-lapping degree of subordination degree, the CI of each sample also shows

Tab.3. Class centroids that that is the average of the character vary for multi-dimensional spatial can reveals the variance of soil character data of the different sample and data combinations (Tan Manzhi, 2006). According to the soil type central value data in the Tab 2, make an appraisal for the soil management zones, the result shows that the content change of soil nutrient character is stability. In the management zone No.1, the content of OM and AN is highest, the nutrient content is richest; on the contrary, the management zone 2 the whole nutrient is lowest; the content of management zones 3anf 4 are in the middle of the range. The output result of fuzzy algorithm method contacts the character spatial and geography spatial distribution information of soil multi-nutrient, it is very important for the variable fertilizer applied, making the management measure in management zones.

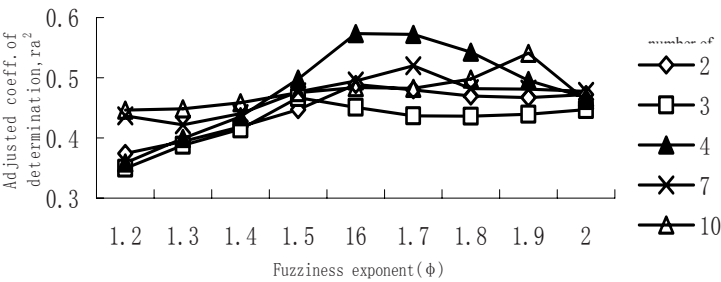


Fig.1: Adjusted coefficient of determination as a function of class partial memberships for different combination of c and ϕ

Tab.2: Class centroids of soil properties

Fuzzy class	OM(g/kg)	AN(mg/kg)	AP(mg/kg)	AK(mg/kg)
C1	13.19	50.62	15.71	411.15
C2	8.19	42.52	10.04	222.89
C3	10.89	47.31	12.48	345.27
C4	9.95	48.18	11.96	293.50

Tab.3: Partial memberships and confusion index of the sampled soils to the classes

Soil sample	C1	C2	C3	C4	CI
1	0.001	0.028	0.014	0.957	0.071
2	0.086	0.022	0.625	0.267	0.643
⋮					
193	0.001	0.944	0.004	0.052	0.108

3.3 Visual express of class result

The spatial information contacted in the output result of fuzzy algorithm method only can as the base of spatial forthcoming and can not directly show

the important act of continuous class in the spatial forthcoming (Tan Manzhi, 2006). So, we need to take the geography-statistics method complete the visual express of the quota subordination relation on the geography spatial for the different soil sample, directly reveal the feature of spatial distribution and variance of soil nutrient on the whole research region, furthermore estimate the soil fertilizer of the research region. On the base of data on the Tab.3, obtain the semi-variance function of subordination degree, and then make the normal kriging method for the partial subordination degree of each soil sample, at last get the subordination degree of the different fuzzy type and reality the spatial forthcoming of soil fertilizer distribution in the research region.

Tab.4: Semivariogram parameters of fuzzy classes

Zones	Model	C ₀ Nugget	C+C ₀ Sill	C ₀ /(C+C ₀)/%	Major Range(km)	Major Range(km)
Zones 1	Guassian model	0.37	2.75	13.46	5.57	2.88
Zones 2	Exponential model	0.56	2.44	23.14	4.35	2.23
Zones 3	Spherical model	0.34	2.93	11.60	6.81	3.47
Zones 4	Spherical model	0.36	2.56	13.87	5.10	2.92

The variance function theory model and their parameter shows in Tab.4. The model of management zone in the No1, 2, 3, 4 is Guassian model, Exponential model, Spherical model, Spherical model respectively. The main axle is change in the range of 4.35~6.81km; Second axle range is change in the range of 2.23~3.47km.The ratio values of C₀/(C+ C₀)/% is lower than 25%, which shows the stronger spatial auto-relation (Chang et al, 1998).

Judged from the Fig.4, the subordination degree of the northern soil for the management zone2 is higher than else region. It is near the Gurbantonggut desert and exist irrigation fixed Aeolian sandy soil family and irrigation soda saline soil Aeolian sandy soil family. There are a great deal of new-cultivated field, the plant age is shorter; the cultivated layer is fuzzy; the ability of conserve water and fertilizer is worse. The soil fertilize is poorer. The subordination degree of the middle soil for the management zone4 is highest (Fig.2d), the region is the distribution of discard yield and main exist the discard saline soil family. The depth of underwater is higher; the water hardness degree is bigger; the content of soil layer is higher; the nature plant is rare; the soil lateral nutrient is lower. the subordination degree of the northern-west and southern-west soil for the management zone3 is higher(Fig.2c), the region main exist the irrigation soda saline gray desert soil family, irrigation SO₄²⁻cl⁻ saline gray desert soil family and irrigation cl⁻SO₄²⁻ saline gray desert soil family and exist the certainty second saline. The soil nutrient content shows the slowly increasing from the west to east and from the southern to northern, the whole fertility level is between the

management zone4 and the management zone1. The subordination degree of the southern soil in the middle part for the management zone1 is higher than 0.8 (Fig.2a). It means the soil nutrient content is highest. It is reason for the distribution the yellow and red texture second type of irrigation-cultivated gray desert soil and sand-gravel texture of irrigation-cultivated gray desert, the ability of conserve of water and fertilizer is stronger than else region, the cultivated age is longer, the degree of cure is higher, the soil nutrient content in the cultivated layer is higher. The oasis management distribution chart on the basis of the subordination degree shows in the Fig.3, which is play a key act for the sole fuzzy subordination degree spatial distribution of soil nutrient.

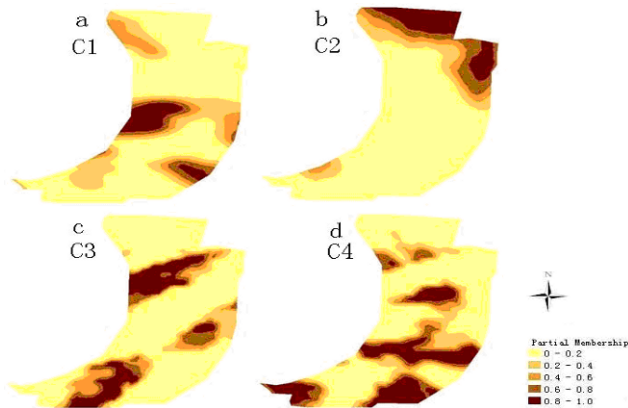


Fig.2: Predictive maps showing spatial variation of partial memberships of soil to individual fuzzy classes derived respective

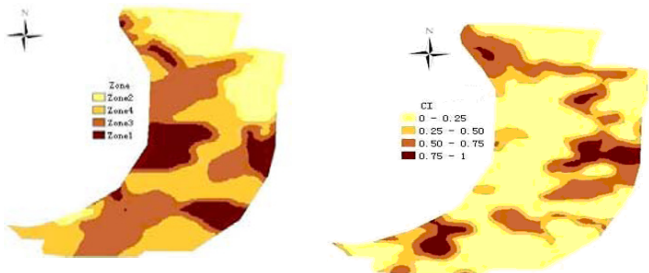


Fig.3: Management zones maps of oasis Fig.4: Predictive maps showing spatial variation of confusion index field

The confusion index means the no-determine complexion of sample spot fuzzy subordination relationship. The value is bigger, the overlapping degree of the different fuzzy type in the sample soil is more higher, no-determine of soil subordination for the sample soil is more higher; on the contrary, it means the lower over-lapping degree, the soil subordination relation is slowly explicit. When CI=0, It means that the character spatial and

geography spatial of sample soil exists the explicit lateral. The confusion index picture is made as following in the Fig.4, from the picture, we can see that the confusion index in the across of new-cultivated, discard and water resource et al and main cultivated field is relative higher. In a certainty zone in the middle and southern in the study zone, CI value is highest, $CI > 0.8$, it shows that in these zones the no-determine of the subordination relationship of soil character content is bigger. The mean value CI of soil subordination relationship is 0.19 in the zone, in the whole view, the no-determine for the fuzzy class output result of soil character data is more smaller, the soil subordination relationship in the spatial geography is relative explicit.

3.4 Check of management zones

In order to determine if management zone is the accordance of vary fertilization, make the normal analysis for the soil character data in the management zone and use LSR method to check the variance sufficient(Tab.4), compared with no divided zones, the vary value of soil character in the each management zone all is reduce. The vary value of OM in the whole zone is reduce from 28.18% to the range of 18.94%~25.57%, the vary AN is reduce from 26.98% to the range of 18.81%~25.15%, the vary value of AP in the whole zone is reduce from 46.03% to the range of 31.46%~42.28%, the vary value of total salt in the whole zone is reduce from 18.32% to the range of 1.53%~13.55%. These are show that the variance degrees all are reduce in the management zones, the content distribution becomes average.

The check of variance sufficient show: judged from 0.05 remarkable level, the mean value of OM and AK both reach sufficient variance in the different zones; the management zones of AN do not reach the sufficient variance between 1 and 3 do not exist; the management zones of AP also do not reach the variance between 2 and 4, between 3 and 4, for the two type nutrient among of else management zones exist the variance. Judged from the 0.01 remarkable level, the management zone of OM between 3 and 4 and the management zone of AN between 1 and 3 do not exist the deficient variance, for the two type nutrient among of else management zones exist the efficient variance; the management zones of AP among of 2, 3 and 4 can not reach the efficient variance, but management zone among of else management zones exist sufficient variance; In the whole view, the spatial distribution variance of soil character in the management zone is more smaller after divided, but the variance among of management zones exist variance. From the pre-text judge that bring the same amount fertilization in the

management inner, but in the different management zones take the different fertilization.

4. DISCUSSIONS

For the fuzzy c-mean algorithm, it needs to determine the management c and fuzzy index φ ; The paper take the multi-fitting method on the basis of extraneous vary to determine the reasonable management zone number and fuzzy index for the different fuzzy type number on the basis of two indexes. The method can better reveal the relationship between the variance of extraneous vary and spatial distribution of subordination degree for fuzzy data collection. The whole zone can provide four management zones, fuzzy lighting exponent is 1.6. the experiment shows that variance value of soil character is reduce compared with the management zones, soil character of management zones is variance efficient, at the same time in the whole zone confusion index is more lower, the overlapping degree for the different fuzzy type is more smaller, the soil subordination relationship in the geography spatial is relative precise. It proves that the measure that management zone is used in the large-scale farmland is feasible. The result of management zone can efficiently express the spatial distribution information of soil character and provide the policy basis for the precise and high efficient field management, at the same time, provided the theory basis in order to study the precise agriculture management.

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A COM-GIS BASED DECISION TREE MODEL IN AGRICULTURAL APPLICATION

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Abstract: The problem of agricultural soil pollution by heavy metals has been receiving an increasing attention in the last few decades. Geostatistics module in ArcGIS, could not however efficiently simulate the spatial distribution of heavy metals with satisfied accuracy when the spatial autocorrelation of the study area severely destroyed by human activities. In this study, the classification and regression tree (CART) has been integrated into ArcGIS using ArcObjects and Visual Basic for Application (VBA) to predict the spatial distribution of soil heavy metals contents in the area severely polluted. This is a great improvement comparing with ordinary Kriging method in ArcGIS. The integrated approach allows for relatively easy, fast, and cost-effective estimation of spatially distributed soil heavy metals pollution.

Key words: ArcGIS; CART; Fuyang; heavy metals pollution; Pb; VBA macro

1. INTRODUCTION

Soils are critical environments where rock, air and water interface. The problem of soil pollution by heavy metals has been receiving an increasing attention in the last few decades. Heavy metals occur naturally in rocks and soils, but increasingly higher quantities of them are being released into the environment by anthropogenic activities. The soil is the primary recipient by design or accident of a myriad of waste products and chemicals used in

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modern industrial society (Brady and Weil, 2002). However, Relationships between heavy metals pollution and environmental factors are often non-parametric and involve complex interactions when humans play an important role in its dynamics. Because of this complexity, common linear and parametric models that try to explain heavy metals pollution with associated environmental variables often do not provide good model fits. The geostatistical methods could not however efficiently simulate the spatial distribution of heavy metals with satisfied accuracy when the spatial autocorrelation of the study area severely destroyed by human activities, for a prior requirement of these methods is to quantify the spatial autocorrelation between properties at different locations so that the information from samples can be weighted into an estimator of the values at unsampled locations (Yao, 1999).

Contemporary GIS applications often include tools to develop customizations that extend the capabilities of the system, thereby presenting the opportunity to link a GIS with even more powerful analytical modules that may not have been previously used for spatial analysis (Crossman et al., 1995). However, there is still no implementation of the decision tree models in the standard functionality of one of the most widespread GIS solutions, ArcGIS. In this study, the integration has been realized in ArcGIS by integrating the classification and regression tree (CART) using ArcObjects and Visual Basic for Application (VBA) into ArcGIS 9.0 to predict the spatial distribution of soil heavy metals contents in the area severely polluted.

2. METHODOLOGY

2.1 Classification and regression tree (CART)

CART enables processing large sets of mixed data, i.e. nominal, ordinal and metric scale data. CART also allows uncovering hierarchical and non-linear relationships among one dependent variable and several predictors. (Schroder et al., 2008) CART handles both categorical and parametric data without data transformation and produces classification results that immediately indicate the variable that significantly discriminates between classes (Schroder, 2006). Generally, CART analysis consists of three basic steps. The first step consists of tree building, during which a tree is built using recursive splitting of nodes. After a large tree is identified, the second stage of the CART methodology uses a pruning procedure that incorporates a minimal cost complexity measure. The result of the pruning procedure is a nested subset of trees starting from the largest tree grown and continuing the

process until only one node of the tree remains (Lee et al., 2006). A testing sample will be used to provide estimates of future classification errors for each subtree. The last stage of the methodology is to select the optimal tree, which corresponds to a tree yielding the lowest testing set error rate.

2.1.1 Building the maximal tree

In this study, we used measure of Gini impurity that used for categorical target variables. The Gini index at node t , $i(t)$, is defined as (Breiman et al., 1984):

$$i(t) = 1 - \sum_{j=1}^n (P_j(t))^2$$

The Gini criterion function for split s at node t is defined as (Kurt et al., 2008):

$$\Delta(s, t) = i(t) - (p_L i(t_L) + p_R i(t_R))$$

where s is the candidate split of a variable v , t the parent node, $i(t)$ the impurity of the node t , p_L and p_R the proportions of objects going to the left (t_L) or right (t_R) child nodes, respectively, $i(t_L)$ and $i(t_R)$ their impurities. Several impurity measures have been proposed as splitting criteria. When a classification tree is being built, three criteria are usually used to choose the best split.

2.1.2 Tree-pruning

This procedure determines a sequence of smaller trees and establishes which is the most accurate by calculating its cost-complexity. The cost-complexity measure R_α is defined as a linear combination of the cost of the tree and its complexity (Caetano et al., 2004):

$$R_\alpha = R(T) + \alpha \left| \overline{T} \right| \Leftrightarrow \alpha = \frac{R_\alpha - R(T)}{\left| \overline{T} \right|}$$

where $R(T)$ is the resubstitution estimated error, which for a classification tree is given by the misclassification error, $\left| \overline{T} \right|$ the size of the sub-tree (number of terminal nodes), and α the complexity parameter. During the pruning procedure α takes values between 0 and 1, and a sequence of nested trees of decreasing size is found.

2.1.3 Selection of the optimal tree

The principle behind selecting the optimal tree is to find a tree with respect to a measure of misclassification cost on the testing dataset (or an independent dataset), so that the information in the learning dataset will not be overfit.

2.2 Implementation of the CART in ArcGIS

By exploiting the modeling power of GIS through integration of GIS with decision tree models, a GIS can be transformed from a simple spatial query and visualization tool to a powerful analytical and spatially distributed modeling tool (Satti et al., 2004). Recent advances in GIS technology facilitate the seamless integration of GIS and computer-based modeling. Some methods for integrating models with GIS have been categorized as 'loose', 'close', or 'tight' coupling. Loose coupling methods usually involve data exchange. An interface program is normally used to convert and organize GIS data into a format required by the model (Liao and Tim, 1997). Close coupling passes information between the GIS and the model via memory-resident data models rather than external files, leading to improved model interactions and performance (Di Luzio et al., 2004). Tightly coupled model integration focuses on incorporating the functional components of one system within the other (i.e. the model within the GIS program) (Liao and Tim, 1997). In this study, the CART has been integrated into ArcGIS using ArcObjects and Visual Basic for Application (VBA) to predict the spatial distribution of soil heavy metals contents. ESRI's ArcGIS 9.0 was chosen because it is widely used, powerful in functionality and allows easy project expansion (Winterton et al., 2004). ArcObjects is a COM compliant, object-oriented programming structure developed by Environmental Systems Research Institute Inc (ESRI). Because ArcObjects are the same software libraries on which the ArcGIS suites of applications are built, any function available in ArcGIS can be implemented programmatically through ArcObjects. Also ArcObjects provides application programming interfaces (APIs) that allow a model developer to programmatically access ArcGIS to automate repetitive tasks and extend its functionality using third-party Component Object Model-compliant (COM-compliant) programming languages such as Visual Basic, C++, Java, or Python. (Stevens et al., 2007)

The integration of the CART model in a geographic information system (GIS) combines decision support methodology with powerful visualization and mapping capabilities which in turn should considerably facilitate the creation of maps that indicating areas with pollution risks.

3. STUDY AREA AND MATERIALS

Fuyang County, situated at the north of Zhejiang Province. The county is located at $119^{\circ}25'00''\sim 120^{\circ}19'30''$ E, $29^{\circ}44'45''\sim 30^{\circ}11'58.5''$ N, and covers a region of 1831 km^2 . The location of the study area is presented in Fig. 1. During the past three decades since economic reform in 1978, industrialization has increased at unprecedented rate, and paper making, mining and smelting are well developed.

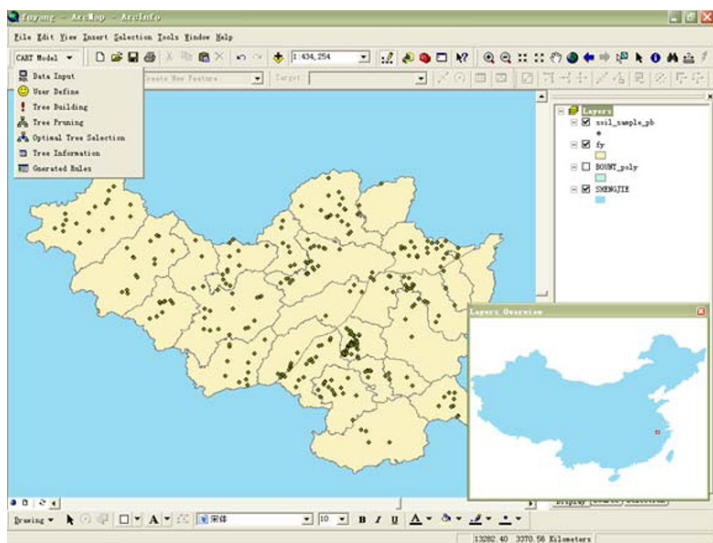


Fig. 1 Location of study area and of sampling points

Soil samples (302) were collected from different locations in March 2005 to take account of uniformity of soil sample distribution and soil types in the study area. The distribution of the 302 soil sampling points is presented in Fig. 1. All samples were taken at a depth of 0-20cm and air-dried to remove stones and coarse plant roots or residues. The samples were thoroughly mixed and ground to pass through a 0.15 mm sieve, then stored in polythene bags for chemical analysis. Pb was determined by digesting the soil sample with a mixture of nitric acid (HNO_3) and perchloric acid (HClO_4) followed by Pb measurement in the digest by atomic absorption spectrometry. Soil pH was determined in a 1:2.5 soil: water ratio and organic matter was determined by wet oxidation at 180°C with a mixture of potassium dichromate and sulfuric acid (Agricultural Chemistry Committee of China, 1983).

The CART model is implemented in VBA (Visual Basic for Applications) and integrated within the ArcObjects. The CART extension is automatically created in ArcMap during installation. When turned on, the extension

operates as a dockable toolbar, similar to other ArcMap extensions. After selecting ‘Data Input’ from the ‘CART model’ pull down menu, a form appears. In our study area, the natural background soil Pb content was set to be 25mg/kg (Zhejiang soil survey office, 1994). The content index was classified into six categories to indicate the level of Pb contamination.

Soil pH was included in the model for it is strongly correlated with soil Pb content determined by the method described here (Zhejiang Soil Survey Office, 1994). The other reason is that soil pH data are often more readily available from soil investigations than heavy metal data, and their value are relatively stable. Agricultural practices such as the use of manure or inorganic fertilizers could add heavy metals to soils, thus the agriculture land use practice was also selected to estimate heavy metals content. There are 7 main agricultural land use in Fuyang county: paddy field (PF), dry land (DL), vegetable land (VT), tea garden (TG), orchard (OR), woodland (WO) and wasteland (WL). The independent variable was named LandUse.

Different industrial plants have different impacts on soil Pb accumulation. The independent variable was named INType.

It has been noted that location close to roads are severally polluted by heavy metals such as Pb, Zn, Cu, Cd, etc. from traffic (Khashman, 2004). The Cd, Cu, Pb and Zn metal contents in road soils and total contents in grasses confirmed the effect of the traffic as source of pollution. To represent the influence of roads, soil samples within 100m, 200m, 300m, 500m, 1000m and outside 1000m main roads buffer zone were respectively selected in this study. The independent variable was named RoadDist.

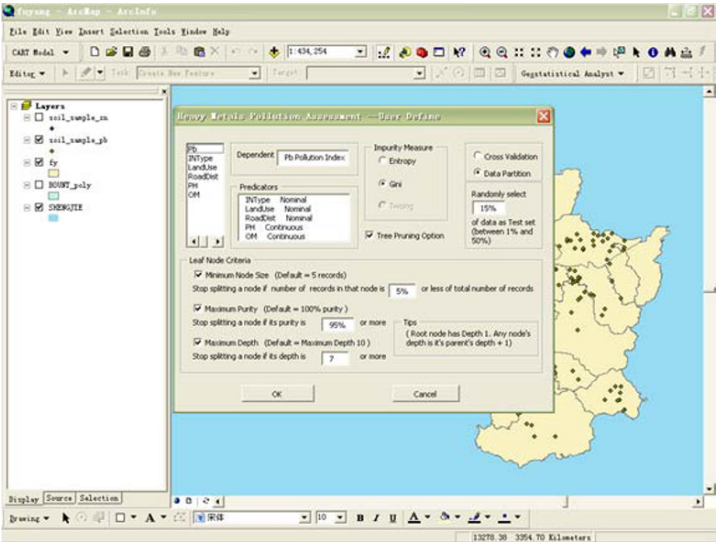


Fig. 2 Main interface of the User Input data of the developed CART VBA macro

The developed VBA macro performs different activities such as extraction of the values of fields and records in the attribute table of the feature class, acquisition of the user input information for estimation of the soil heavy metals pollution. The overall goal of the CART analysis is to devise models that will use the predictor variables to predict the values of the response variable in a non-parametric way. A minimum node size of five or 1% of total number of dataset (records) was applied in the CART, the maximum tree depth or maximum purity also can be specified in the VBA macro. The data here is divided into two subsets, one for learning and the other for testing. The learning sample is used to split nodes, while the testing sample is used to compare the misclassification (see Fig. 2).

The developed VBA macro calculates classes that are homogeneous with respect to the features of the dependent variable (here the soil Pb content). It identifies the predictor variables with the highest correlation with soil Pb content by splitting the data set into the two most dissimilar groups. The splitting of the data set and tree development continue until the data in each group are sufficiently uniform. The method here partitions the data set into six discrete subgroups, based on the classification value of the dependent variable. The CART VBA macro finally produces a set of rules to allocate samples to predefined classes. The rules are important in two ways. First, they are used to predict the values of the dependent (response) variable. Second, they contain a wealth of information about the relationship between the response and the predictor variables and the interactions among the predictors. (Li, 2006)

4. RESULTS AND DISCUSSION

The ArcGIS tool with built-in macro programming languages and Component Object Model (COM) compliant protocols facilitated the integration of different data structures and programming logics (Sarangi et al. 2004). The confusion matrix (see Fig. 3) shows the relationship between measured and estimated Pb classes. The total accuracy refers to the ratio of total number of correctly inferred Pb classes divided by the total number of samples (training, test data respectively); and the Kappa Coefficient uses all of the information in the confusion matrix, ranging from 0 to 1. The overall CART accuracy of assigning samples to the right Pb classes is 89.62% and 85.71%, the Kappa coefficient is 0.8444 and 0.7575 respectively for training data and test data. The samples used in CART were also used in Kriging, Geostatistics module in ArcGIS, to estimate Pb content spatially. Kriging estimates variable values at unknown locations from a semi-variogram model and appropriately sampled data set. Kriging uses the semi-variogram

to quantify the spatial variation..The total accuracy of assigning kriged estimates of Pb classes to measured values is 42.65%, and the corresponding Kappa coefficient is 0.47. The main reason for increased accuracy might be that Pb content in this study area is greatly influenced by human activities leading to localized sharp variations and hotspots which are smoothed over by Kriging with a long range variogram.

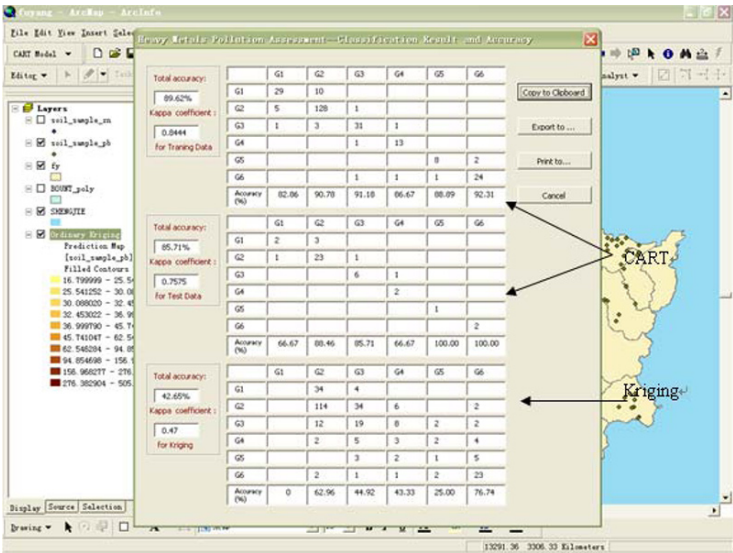


Fig.3 The result of the CART model and the kriging method

5. CONCLUSION

The developed CART VBA macro integrates all the components described in the methodology section to the user and allows the configuration, prediction, visualization and analysis of the model outcomes in the same environment thereby providing simplicity and flexibility. Code was written in VBA and deployed as a template file from which any ArcGIS project can be derived. Also the CART model is easy to apply and the functions are accessible by users who do not have expert knowledge of modeling and programming.

The described VBA macro which implements the CART model is a useful tool for assessment of heavy metals pollution. The presented VBA macro fills an important gap in the ArcGIS functionality, since the decision tree models does not belong to the standard functionality of this widely used GIS. The integrated approach allows for relatively easy, fast, and cost-effective estimation of spatially distributed soil heavy metals pollution. The methods and results described in this study are valuable for understanding the

relationship between heavy metals pollution risk and environmental factors. Also the description of the macro provided a template not only for users who are working in the field of heavy metals pollution assessment but also in other fields of geosciences.

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STUDY ON SOIL SPECIAL VARIABILITY AND CROPS OPTIMAL LAYOUT BASED ON GIS IN THE WEST-NORTHERN PLATEAU OF HEBEI PROVINCE

Taking Desheng Basin in Zhangbei County as An Example

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Abstract: A geo-statistics method combined with GIS was applied to study the soil special variation characteristics of a typical basin on the Northwestern Plateau of Hebei Province. It indicates that the rational crop layout is determined by the soil texture. And the crop layout optimization schemes were put forward for different production objectives based on the GIS platform with the soil-crops special co-adaptation. The results showed that basin altitude was the primary cause for the special variation of soil texture and nutrient content. The crop layout optimization schemes showed that the economic efficiency was increased by 26.9%~48.5% in large-scale of crop production, while the economic efficiency was increased by only 8.0%~8.5% with ecological construction of de-farming. It was concluded that the agricultural production progress should mostly rely on the renovation of farming organization system and the scale of economy should be the primary impetus for agricultural development in the Northwestern Plateau of Hebei Province.

Key words: spatial variation of soil, crop layout, soil texture, the Northwestern Plateau of Hebei Province

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1. INTRODUCTION

Soil is a continuous spatial-temporal heterogeneity. The study and application of soil spatial variation regulation is the basic gist for rational land resource utilization and crop layout. The GIS technique is an effective way to allocate crops with local conditions because of its storage and analysis ability of the massive natural resource spatial data. And GIS has been widely applied from spatial distribution and variability characteristic of soils in small scale to suitable climatic regionalization of vegetations in large scale. Precise spatial data provide the basis for soil classification and management (Cambardella, 1994; Jose, 2000; Huang, 2003; Yuan, 2008). At the same time crop adaptability database based on GIS provides quick response technology to production structure adjustment and hazard prediction (Pan, 2000; Yao, 2004; Ji, 2007; Yao, 2008). Crop layout optimization based on soil spatial variation combined with crop adaptability has been a problem to be solved by agronomist and farming manager (Wang, 2007). The development of GIS and related computer technology showed a new thought for the question. This paper analyzes the soil spatial variation and its influence on crop layout of a typical geomorphic unit in northwestern plateau of Hebei Province and discusses the coupling relationship between soil and crop. And the crop layout optimization schemes for different targets were put forward to further provide the technological basis for structure and function improvement of crop production system in the northwestern plateau of Hebei Province.

2. STUDY ZONE DESCRIPTION AND METHODS

The northwestern plateau of Hebei Province lies at the southeast edge of Inner Mongolia plateau. The altitude ranges from 1300 m to 1600 m. And the area is characterized as slope land and shoaly land with staggered distribution. The wavy terrain results in remarkably special differentiation of the secondary resource with the characteristic of soil special differentiation. Because of the long-time unscientific and predatory agricultural production it caused severe soil erosion and desertification. It is one of the nearest resources for sand-dust to Beijing. So crop spatial layout optimization aimed to economic development and ecological restoration has become one of the most important active demands for regional society development.

The study zone lies on the eastern slope of Desheng Village, Zhangbei County, Hebei province, China and its terrain is relatively independent (41.19°N, 14.84°E and 1405.2~1416.2m above the sea level). The total area of the zone is 242762.8m². It includes 219900m² of farmland, 12536.9m² of low grassland, 6256.3m² of forestland, and 4069.6m² other-use lands. Crops

are mainly oat, sugar beet, potato, kidney bean and forage maize. The natural conditions in Desheng Basin represent the northwestern plateau of Hebei Province.

3. STUDY METHODS

Using the Ag GPS-132 differential receiver made by Trimble Corporation, the Desheng Basin was divided into seventy-eight nodes with one node of 50m×50m and measured with located position (Fig.1). Each node measured the total nitrogen content, available phosphorus, available potassium and organic matter contents and soil mechanical composition in the upper 20 cm soil layer. Using the software of SUPERMAP with the input value of the basin altitude, soil nutrient and its mechanical composition was quantified and interpolated. Then the map of variation in the soil was drawn.

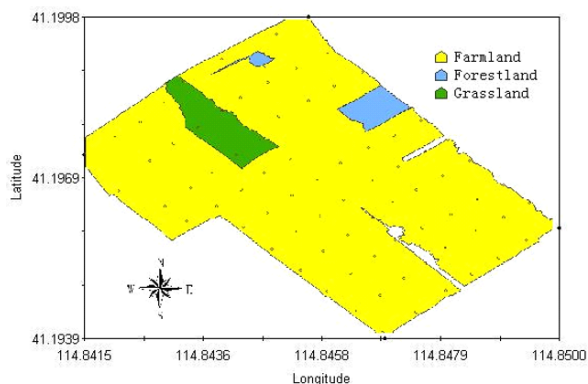


Fig. 1 The map of node distribution

The soil organic matter content, total nitrogen content, available phosphorus content and available potassium content were determined by Potassium Dichromate Titrimetric Method, Semi-Micro Kjeldahl Method, NaHCO_3 extraction-ammonium molybdate-tartaric emetic-ascorbic acid colorimetry, and ammonium acetate extracting-flame spectrophotometry method, respectively. Soil mechanical composition was determined by hydrometer method.

The yield of different crops was actually measured through three sample areas of 1m^2 in each node. The cost and price of crop product were obtained through household investigation. Crop layout was designed with linear optimization.

4. RESULTS AND ANALYSES

4.1 The spatial variation of soil characteristics

Fig.2 showed that the altitude of Desheng basin fluctuated from 1405.2m to 1416.2m with a low height difference and gentle incline from 0° to 5°. The mid and northwest part of the basin was lower, and the other part was higher, so the terrain of the basin formed a dust-pan shape. In small scale, the soil formation process and mechanism was similar, but due to terrain difference, substance and energy were redistributed in different nodes, and resulted in the variance of soil texture and nutrient in the basin. The soil organic matter, total nitrogen, and available potassium contents in the low mid and northwest parts of the basin were higher than those in the other parts, and with increase of altitude along the slope the soil nutrient content decreased (Fig.3, Fig.4, and Fig.5). Soil clay content in the lower mid part was also higher than the other parts of the basin except the mid part, in which the soil clay content decreased due to higher altitude (Fig.7). There was no rule for the change of available phosphorus content because of the poor movement of phosphorus and different fertilizer application in different nodes (Fig.6).

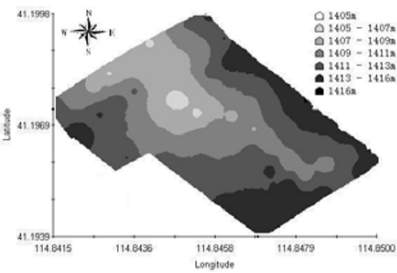


Fig.2 The contour map of Desheng Basin altitude

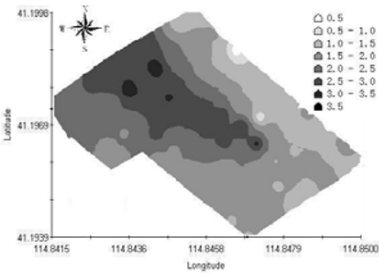


Fig.3 The contour map of the soil organic matter in Desheng Basin

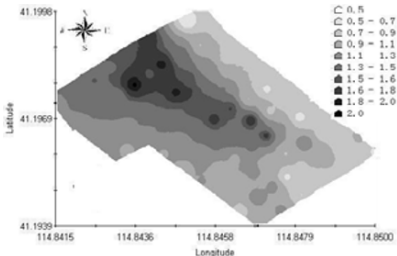


Fig.4 The contour map of the total nitrogen content in Desheng Basin

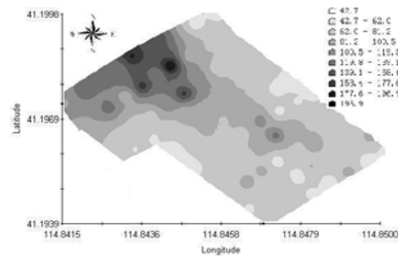


Fig.5 The contour map of the available potassium content in Desheng Basin

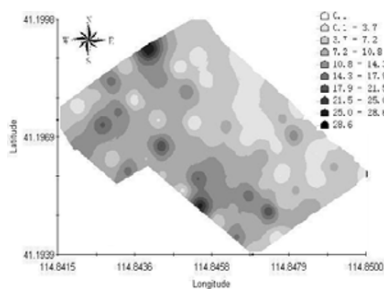


Fig.6 The contour map of available phosphorus in Desheng Basin

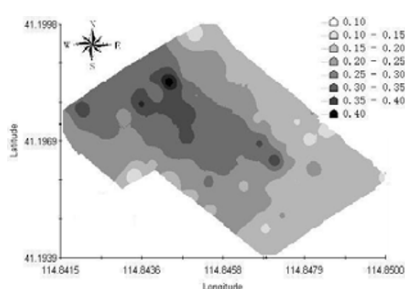


Fig7 The contour map of soil clay in Desheng Basin

Since the soil formation process was continuous in time domain, the soil texture change was continuous in space domain. The Semivariance analysis of soil characteristic data showed that soil nutrients and texture were significantly correlated with the altitude of the basin, and available phosphorus content in the soil was moderately correlated with the altitude. In small scale in the soil formation factors, the climate and soil parent material were consistent, so the difference between different nodes attributed to the difference of the terrain and altitude of the basin (Table 1).

Table1. Semivariogram models of soil nutrients and corresponding parameters

Item	Theory model	Nugget	Still	Nugget/Still (%)	R ²	RSS	Range(m)
Organic matter (g/kg)	Exponential	0.1030	1.3050	13.01	0.96	0.0372	57
Total nitrogen (g/kg)	Exponential	0.1570	1.8030	8.71	0.94	0.0813	114
Available phosphorus (mg/kg)	Exponential	0.7260	1.4530	49.97	0.80	0.0414	180
Available potassium (mg/kg)	Spherical	0.2730	2.3860	11.44	0.92	0.173	125
Soil clay (%)	Exponential	0.255	1.407	18.12	0.921	0.0638	75

The correlation analysis of soil characteristic data in each node showed that soil total nitrogen content, available potassium content, organic matter content, soil texture and altitude were significantly inter-correlated, but inter-correlation between available phosphorus and other soil characteristic was not remarkable (Table2). Soil formation was a complicated and long process, the soil texture, especially the composition proportion of physical clay, directly affects formation of soil aggregated structure, nutrients mineralization and fertilizer-water preserving capability of soil. Under the condition of little human activity, the soil texture affected and determined its nutrients content. For the farmland with extensive management in the basin, the soil texture was the effective classification standard.

Table2 The correlation analysis of the soil characteristic data

Item	Organic matter (g/kg)	Total nitrogen (g/kg)	Available phosphorus (g/kg)	Available potassium (g/kg)	Soil clay (%)	Altitude (m)
Organic matter (g/kg)	1					
Total nitrogen (g/kg)	0.94**	1				
Available phosphorus (g/kg)	0.26*	0.26*	1			
Available potassium(g/kg)	0.75**	0.77**	0.18	1		
Soil clay (%)	0.84**	0.86**	0.18	0.77**	1	
Altitude (m)	-0.78**	-0.73**	-0.13	-0.65**	-0.69**	1

4.2 The crop production effect in different soil types

The soil in the basin was generally classified into two types: sand chestnut soil and meadow chestnut soil (Shi, 1995). The classification standard was too simple and rough to reflect the continuous variation of the soil texture. For example, the <0.01 mm physical clay content was measured with a range between 10.7% and 43.1%, while according to the soil classification system of Кацинский, the soil should be sandy loam to medium loam. According to the integration of the two classification systems, the farmland in the basin should be classified into four grades (Table 3).

Table3. The farmland classification and its area

Item	Grade one	Grade tow	Grade three	Grade four
Content of physical clay (%)	43.1~30	30~25	25~20	20~10.7
Soil texture	medium loam	light loam	Light-sandy loam	sandy loam
Area (m ²)	7301	58035	70710	83853

The area and distribution of each grade was shown in Fig.8. In Desheng Basin, the area of NO.4 grade of farmland was the largest in the four grades, while that of NO.1 grade was the smallest. Marsh was located in the mid of the basin and it was not suitable for farming.



Fig.8 The map for the farmland classification in Desheng Basin

The terrain characterized as soil texture change affected crop yields by water and soil resource redistribution. Table 4 showed that the yields of sugar beet, oat and forage maize in different grade of farmland decreased as the soil texture became inferior. The yields of potato and kidney bean in the farmland of NO.2 grade were highest among all the grades of farmland. So these two crops were adaptive to sandy soil. There was significant difference among the yields of crops in different soil texture types of farmland. Under the condition of current extensive management, the difference of crop yields reflected the soil texture change. According to the production effect of crops in the different grade of farmland, crop re-layout should gain a better production effect than cultivation technology renovation.

Table 4. The production effect of the crops in different grades of farmland

Farmland grade	Items	Sugar beet	Oat	Potato	Forage maize	Kidney bean
Grade one	Yield (kg/ m ²)	3.825a	0.177a	1.633a	4.078a	0.152b
	Output value(¥ yuan/m ²)	0.629	0.155	0.39	0.393	0.106
Grade two	Yield (kg/ m ²)	3.219b	0.157b	1.665a	3.489b	0.176a
	Output value (¥ yuan/m ²)	0.435	0.095	0.412	0.299	0.166
Grade three	Yield (kg/ m ²)	2.363c	0.143c	1.328b	2.531c	0.122c
	Output value (¥ yuan/m ²)	0.161	0.053	0.183	0.146	0.031
Grade four	Yield (kg/ m ²)	1.931d	0.137d	1.1c	1.721d	0.103d
	Output value (¥ yuan/m ²)	0.023	0.034	0.028	0.016	-0.017

4.3 Optimization strategy for crop layout

Table 5 and Fig.9~12 showed the results of crop layout optimization with the linear programming method according to the soil texture. Under the precondition that the total yield of the crops would not decrease and the cultivated area of all grades of the farmland would be decreased with equal ratio. The Optimization Scheme I could decrease cultivated farmland area (L) by 6.8% and the economic efficiency (B) was increased by 8.0%.

It indicated that the project of returning cultivated land to forest and grass without subsidy from government could be carried out with technical approach. The land equivalent ratio (L') after crop layout optimization was only 1.073 indicating that the current crop layout was basically reasonable and the farmland was basically reasonably utilized. The straight strip planting along slope was the primary cause for restricting yield. The traditional farming mode has made the farmland basically play its productive potential.

Under the precondition that the total yield of the crops would not decrease and the farmland was cultivated with the minimum area, with the

Optimization Scheme II crops should be first planted in the farmland of grade one to three and part of the NO.4 grade farmland was left for de-farming with 17513m², i.e., by the crop layout optimization the de-farming area occupied 7.9% of the total farmland. At the same time, the economic efficiency was increased by 2612¥ with an increase ratio of 8.5%. So it was concluded that carrying out de-farming with technical approach could make economic efficiency increased by only 8.0%~8.5% and in closed ecosystem of returning farmland to grass and/or forest was short of impetus for economic profit.

Table5. Optimization scheme for crop layout

No.	Items	Sugar beet (m ²)	Oat (m ²)	Potato (m ²)	Forage maize (m ²)	Kidney soybean (m ²)	Total (m ²)	Data of original crop layout	Equivalent effect ratio (%)
I	Grade one	6805					6805	7301	L=6.8 L'=1. 073
	Grade two	19588			7220	27281	54089	58035	
	Grade three	47140	8097	10665			65902	70710	
	Grade four		77810				77810	83853	B=8.0
	Output value ¥yuan	22510	3069	1951	1453	4212	33195	30718	
	Precondition	Maintaining current yield with minimum farmland utilization for de-farming with equal ratio							
II	Grade one	7301.3					7301	7301	L=7.9
	Grade two	23534			7220	27281	58035	58035	
	Grade three	40961	19084	10665			70710	70710	
	Grade four		66340				66340	83853	B=8.5
	Output value ¥yuan	21424	3267	1952	2159	4529	33331	30718	
	Precondition	Maintaining current yield with minimum farmland utilization							
III	Grade one	7301					7301	7301	
	Grade two	58035					58035	58035	
	Grade three		2307	19093	9953	39357	70710	70710	
	Grade four		83853				83853	83853	B=26.9
	Output value ¥yuan	29838	2973	3494	1453	1220	38978	30718	
	Precondition	Maintaining current yield with maximum economic efficiency							
IV	Grade one	7301					7301	7301	
	Grade two	58035					58035	58035	
	Grade three			70710			70710	70710	
	Grade four		83853				83853	83853	B=48.5
	Output value ¥yuan	29838	2851	12940			45629	30718	
	Precondition	Large-scale maximum economic efficiency							

Under the precondition of maintaining current yield of crops to pursue maximum economic profit, the Optimization Scheme III could increase the economic efficiency by 26.9%. The kind of crop layout need to break down the current crop planting pattern with straight strip planting along slope and farmland use pattern to realize scale profits by renovating farmland distribution modes. According to the standard that pursuing maximum

economic profit was the unique objective without affecting the original crop layout and productive effect, the Optimization Scheme IV could increase the economic efficiency by 48.5% compared with the original crop layout, but the new crop layout need crop production to realize complete marketization, large-scale and independent management.

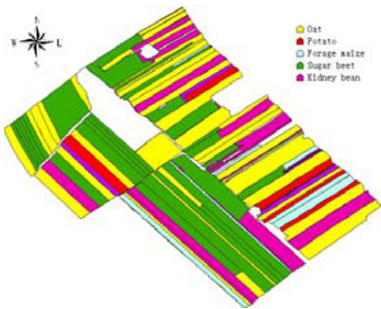


Fig.9 Original crops layout



Fig.10 Optimization Scheme I

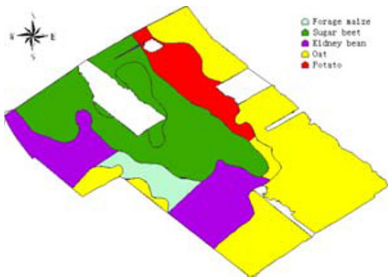


Fig.11 Optimization Scheme II

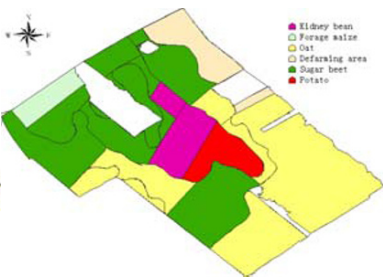


Fig.12 Optimization Scheme III

5. CONCLUSIONS

In the typical basin of the northwest Plateau of Hebei Province the soil texture was significantly correlated with the terrain and altitude of the basin. Furthermore, the soil nutrient contents were significantly correlated with the soil texture. The soil clay content was the most stable factor of soil texture, and it should be regarded as the basic criteria for distinguishing soil types.

There were significant differences among the yields of crops in different soil texture types of farmland. The difference reflected the soil texture change. In the current closed ecosystem, the economic efficiency could be increased by 26.9% by renovating the farming technologies, but by building open agro-system, especially by rationally regional crop layout in large-scale would increase the economic efficiency by 48.5%. Implementing de-farming with the production technology renovation could increase the economic

efficiency by only 8.0%~8.5%, so returning farmland to grass and/or forest has to rely on subsidy from government. So in the Northwestern Plateau of Hebei Province the agricultural development should rely on organization system renovation of agricultural production to a greater extent. Large-scale economy would become a new economic growth point for agricultural development.

6. DISCUSSION

The geo-statistics method based on spatial correlation theories effectively illuminated the special relation and difference between different soil samples, and could reflect the special characteristics and variation rules between crops and soils more precisely than traditional statistical method (Cambell,1978; Webster, 2000; Jiang,2001). It was the basis for developing precise agriculture. The study established a platform of special coupling between soils and crops based on special variation of soil nutrients, and found the crop layout optimization schemes for different production objectives with the linear programming method. The united application of geo-statistics and GIS technology and linear programming method realized the crop optimization layout accurately. The study should be regarded as a significant attempt to change “black-box operation” into “white-box control” in precise agriculture application for crop production.

Soil texture is an important environment factor for crop growth. In large scale, soil texture is the primary gist for soil classification and rational crop layout. But in small scale, with the enhancement in cultivation factors including water-fertilizer application and cultivating-planting practices, the soil texture effect on crop layout was easily neglected. In the northwestern plateau of Hebei Province, soil formation was affected by the terrain and wind-water erosion. There was significant difference between different soil nodes. At the same time, because of extensive agricultural production, soil texture became a relative stable factor for evaluating soil fertility level. The recent studies showed that even if on the farmland with intensive management, soil texture also significantly affected water-fertilizer use efficiency so as to be regarded as a primarily important factor for crop layout (Jiang, 2006; Li, 2007; Cui, 2007). Hence, the soil regionalization based on soil special variation possessed a significant actual-guiding role for precise agriculture development.

The analysis for crop layout optimization showed that in current closed farming system the existing crop layout basically made the farmland realize its maximum function. By the renovation of crop production technologies, the potential to further increase farming productivity was limited. The agricultural productivity could be emancipated to a great extent by breaking

down the current crop planting pattern and realizing a large-scale crop production. However, the productivity enhancement would further rely on the organization system renovation of agricultural production. This required a perfect market mechanism and effective production-market cooperation between different regions (Zhang, 2008). In China, the traditional crop layout and regionalization regarded “the principle of adjusting measures to local conditions” as guiding ideology it neglected the function of market and organization mechanism to effectively dispose agricultural resource. Thus, the guiding function of market and organization turned weaker and weaker. Some agricultural scientists from FAO point out that most of farmland exploitation projects in some developing countries did not achieve expected effect or even failed because the projects neglected the economic and social attributes of farmland (Yu, 1994). Under the background of open agriculture, the regional agricultural predominance must be made clear, and then correct agricultural production decisions can be made. Information theory and technology provided an effective approach or thinking frame for making scientific agricultural policy.

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RESEARCH AND APPLICATION OF PRECISION FERTILIZATION ON MAIZE

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Abstract: The current precision fertilization technology of maize is still incomplete and unsystematic. In the paper, according to the fact of maize production of black soil zone in Jilin province, spatial variability of soil nutrient is studied, precision fertilization model of maize is introduced, a web-based expert system for maize precision fertilization is developed. Finally, the precision fertilization is implemented by the variable rate fertilizer. The practice shows that, by the program proposed in this paper, the maize yield was increased by nearly 10%, and the fertilizer was saved about 10.5%. Furthermore, the profit and maize quality was increased and the environmental pollution and input cost was decreased.

Keywords: maize, precision fertilization, spatial variability, expert system

1. INTRODUCTION

Precision fertilization is the key part of precision agriculture. The implementation of precision fertilization can Save fertilizer, increase food production (GAO Xiang-zhao, HU Ke-lin, etc. 2002) and balance soil nutrients (Zhang Shuhui, Ma Chenglin, Li We i, Xu Yan, etc. 2006). Maize is China's important food crops. Black soil area in Jilin Province is the prime maize

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growing areas. Precision fertilization is of great significance for black soil area in Jilin Province to reduce fertilizer inputs, increase maize production and improve maize quality.

The key technologies of Precision fertilization include the following three points. Firstly, it should be based on the spatial variation of soil nutrients to implement the accuracy of soil nutrient testing and crop nutrients diagnosing. Secondly, appropriate fertilization model should be determined to implement the precision of fertilizer amount. Thirdly, good fertilization machines should be selected to implement variable rate fertilization.

Spatial variation analysis of soil nutrients is the basis of precision fertilization, the aim of which is to determine management zones. There are three methods to determine management zones, which are cluster analysis, primary component analysis and space variation coefficient(Rodrigo A,Ortega,etc.2007).

In the research and practice of recommended fertilization for crop, there are as many as over 60 kinds of fertilizer model. However, there exist many contradictions between these fertilizer models and the current production practice. Also, large amounts of accumulated data can't be used to direct the production practice(Hou yanlin, Chen shoulun.2004).

In the fertilization practice, there are still a lot of uncertainty and complexity, which indicates that the experience of agricultural domain experts is essential.

So, how to combine the experience of human expert and fertilization model is very important. Fortunately, an expert system about maize precision fertilization was developed, which can solve the above problem effectively. In the future, the expert system will be distributed and service-oriented (Edson Murakami,Antonia M.Saraiva,et al.2007).

2. TECHNICAL ROUTES OF MAIZE PRECISION FERTILIZATION

Maize precision fertilization is composed of four steps: data collection, analysis of soil spatial variation, determination of fertilization model and application of precision fertilization. The detail is as follows:

(1) Data collection

- ①Sampling nutrient data and yield data by GPS and sensor
- ②Grid plotting by GIS
- ③Sampling, analyzing and testing of soil

(2)Data Analysis

- ①Building the spatial database and attribute database

②Plotting spatial variation map of soil nutrient, exploring the spatial variation law

③Determining and optimizing the sampling mode and layout

(3) selection of fertilization model

①Evaluating and preferring existing model

②Fertilization model fusion

③Determination of appropriate fertilization model

(4) Application of precision fertilization

①Developing precision fertilization expert system

②Import the fertilization prescription into the field computer

③Implementing the precision fertilization

3. DATA COLLECTION

The experimental Field is located in Gongpeng town, one town of Yushu City in Jilin, which is typical of the black soil zone.

In the experimental site, the perimeter of the area of study was demarked with DGPS. The area of the experimental field is 17hm². The sampling grid is 40m×40m and 105 samples were achieved. Fig.1 is the grid map of the experimental site. After soil sampling, the soil NPK was tested by chemical method.

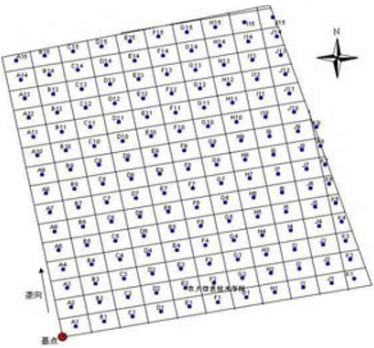


Fig.1 The grid map of the experimental site.

4. THE SPATIAL VARIABILITY ANALYSIS OF THE SOIL NUTRIENT

The spatial variability analysis is based on two methods. One is conventional statistics, which can provide basis for determining the number

of samples and the grid layout. The other is geo-statistics analysis, which can provide basis for precision fertilization and management zones(Zhang Shujuan, He Yong , Fang Hui.2003) .

4.1 Conventional statistics

The parameters based on conventional statistics can be seen from table 1.It shows that the spatial variation of P is the largest and the C.V(coefficient of variation)is 52.86%; The spatial variability of N an K is small and the C.V is 9.6% and 5.99% respectively. According the above results and the fertilizer need of maize in seedling stage, we can conclude that the variable rate fertilization of maize in black soil area is mainly variable rate of P.

Table 1. The statistics value of soil nutrient content

Item	Minimum	Maximum	Mean	S.D.	Skewness	Kurtosis	C.V. (%)
N(mg·kg ⁻¹)	90.8	175.6	114.485	10.992	0.740	0.573	9.60
P(mg·kg ⁻¹)	10.55	415.20	49.6952	26.2706	7.454	83.789	52.86
K(mg·kg ⁻¹)	95	182	156.80	9.39	-1.301	3.652	5.99

4.2 Geo-statistics analysis

By model fitting for nutrient data and Cross-Validation for parameter revision, with ArcGIS, Optimal semi-variogram theoretical model and its parameters were achieved (Table 2).

Table 2. Semi-variation model and some parameters in the experimental field

Variables	Fitting model	Nugget	Partial Sill	Range(m)	Nugget/Sill(%)
N	Pentasppherical	22.998	38.987	291.63	37.10
P	Exponential	0.092	0.131	405.42	41.21
K	Hole Effect	27.372	15.829	355.95	63.36

From Table 2,we can see that spatial correlation of N and P is relatively high, and yet K is low. The variation of the range of soil nutrient content is not large, varying from 226.66m to 405.42m, and the range of P is the largest, which is 405.42m.

By Ordinary Kriging method in Geo-statistics, The spatial variability map of NPK can be achieved(Fig.2).

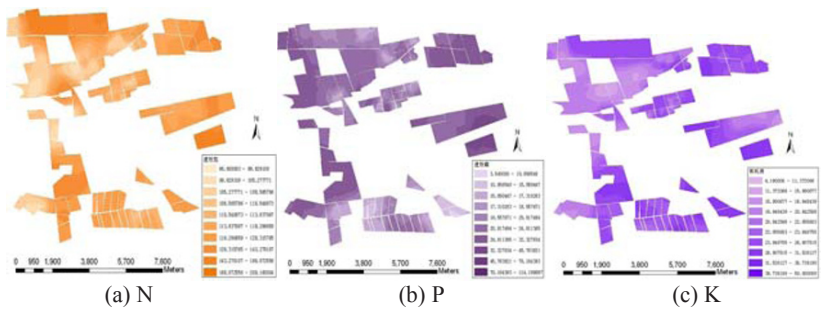


Fig.2 Spatial variability map of NPK

5. THE DETERMINATION OF FERTILIZATION AMOUNT

5.1 Fertilization scheme

Precision fertilization for maize is divided into two phases, namely subsoil fertilizer and additional fertilizer phase. Subsoil fertilizer amount is achieved by the optimization and fusion of the existing fertilizing model and based on soil nutrient。 Additional fertilizer amount is achieved by crop nutrient diagnosis based on remote sensor.

According to the character of maize’s growth and development, In the subsoil fertilizer phase, N and P should be fertilized when the maize growth is during seedling period. In the additional fertilizer phase, N should be fertilized when the maize growth is metaphase. Obviously, N is fertilized in the two phases. N fertilizer amount of seedling period mainly comes from subsoil compound fertilizer which includes a part of N. According to the expert experience, the need of N of spring maize during seedling stage is approximately 30-50kg/hm², fortunately, which is nearly the same as the N amount contained in subsoil compound fertilizer. So, in subsoil fertilization phase, the main task is to compute the P amount.

5.2 The determination of subsoil fertilizer amount

Fertilizer amount can be determined by three steps. Firstly, method of soil fertility indicators was used to achieve the range of fertilizer amount. Secondly, according to the level of variety liking fertilizer, another range of fertilizer amount was achieved; Thirdly, by the nutrient balance formula, the concrete fertilizer amount is computed, then taking soil fertility

indicators and level of variety liking fertilizer into account , the final fertilizer amount is determined.

(1) Determining the range of fertilizer amount by the method of soil fertility indicators

According to the soil testing and fertilizer recommendations in Jilin province and the initial result of “3414”experiment, P level in the black soil was classified([Table 3](#)).

Table 3. The level of P and corresponding fertilization amount in experimental field

P (mg/kg)	6~19	19~27	>27
Fertilizer amount with maximum yield(kg)	76±17	70±14	66±17
Fertilizer amount with economic optimum(kg)	64±12	55±18	57±15

(2) Providing reference for determination of fertilization amount by the attribute of maize needing fertilizer

As for the different maize variety, there exists much difference in the need for fertilizer(Xie Jia-gui, Wang Li-chun, etc.2006).According to coefficient of fertilizer absorption and coefficient of fertilizer effect, level of maize liking fertilizer can be divided into three grades, which are high, medium and low. Each level has its corresponding fertilizer amount with economic optimum([Table 4](#))

Table 4. The degree of maize response to nutrient and corresponding fertilization amount

Response degree	High			Middle			Low		
Fertilizer category	N	P	K	N	P	K	N	P	K
Fertilization amount(kg/hm ²)	225±25	85±20	110±20	190±25	70±20	90±20	165±25	60±20	80±20

(3) Determining the fertilizer amount of each grid by soil nutrient balance formula

The nutrient balance formula is as follows: $F=(Y\times C-S)/(N\times E)$
In which, F: fertilization amount(kg/hm²); Y: target yield(kg/hm²); C: nutrients absorption of unit yield(kg); S: Supply of nutrients in the soil (kg/hm²) ; N: nutrient ratio in the fertilizer(%); E: Quarter utilization rate of fertilizer (%) ; S= value of soil nutrients×Soil nutrient conversion factor.

In order to use this formula, the key is to determine the value of parameters, which is achieved by the actual production situation and the results of previous studies.

According to the actual situation in the field, the target yield was set 8500 kg/hm² ;other parameters as follows: phosphorus absorption capacity of 100 kilograms of maize grain is 1.15 kilograms; phosphorus conversion factor is 1/(0.1674+0.03579×value of phosphorus)×1.5 ; the P₂O₅ ratio in the

compound fertilizer is 18%; quarter utilization rate of fertilizer in black soil is 20%.

By this formula, the fertilizer amount can be computed.

(4) The determination of additional fertilizer amount

As we have discussed, in the additional fertilizer stage, the fertilizer used is N. The amount of N can be achieved by two methods. One method is to compute total N by nutrient balance formula, then the amount of additional N fertilizer is the total N minus the amount of subsoil N fertilizer. The other method of computing additional N fertilizer is by plant nutrient diagnosis, which takes into account the real time state of maize growing, so the computed fertilizer amount by this method is more precise. However, as far as the cost is concerned, the first method is adopted in this paper.

6. THE APPLICATION OF PRECISION FERTILIZATION ON MAIZE IN BLACK SOIL AREA

6.1 The implementation of web-based expert system for maize precision fertilization

The function of expert system is to achieve fertilization prescription. A PC-based fertilizer expert system has been developed (CHEN Gui-fen, WANG Yue, WANG Guo-wei.2006). In order to make user access the expert system through internet and alleviate the burden of the client computer, we developed a web based expert system, which is composed of seven modules: production forecasts, variety selection, rational fertilization, profit analysis, advisory printing, data statistics and maintenance.

Database, knowledge base and model base are core of the expert system, in which, knowledge base and model base extract data from database and cope with each other to give fertilizer recommendation.

In the knowledge base, rule-based knowledge representation was used, its form is as follows:

IF (condition 1) & (condition 2) THEN (conclusion)

This is a production rule, in which, the IF clause is called premise, the THEN clause is called consequences. The advantage of using production rule to represent agricultural knowledge is that it has simple form and strong representation capacity and can be understood easily.

The model base in the web based expert system mainly includes the following fertilization models: nutrient balance model, fertilizer response function model, nutrient abundant index model and the property of maize liking nutrient model. The developer or the user can choose different model according to the actual situation.

6.2 Fertilization amount recommendation and implementation of precision fertilization

Fertilization prescription map can be achieved by expert system, then it will be imported into the variable rate fertilization machine.

The variable rate fertilization machine adopted in this experiment is adapted by suction seeder, and is of dual function of precision seeding and precision fertilizing. In order to implement the precision fertilization, a field computer is adopted in this machine to control the fluid power system directly (QU Gui-bao, TIAN-yun.2005).

Fluted roller feed distributor is adopted to implement the fertilizer distribution. The range of variable rate fertilization is 0~675kg/ha, the precision of which is 5~10% and the working width is 3~5m. The operating principle can be seen in Fig.3.

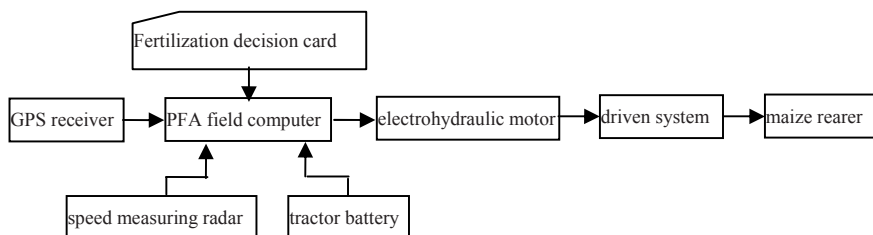


Fig.3 The operating principle of variable rate machine

In the year 2007, precision fertilization was implemented in the experimental site. The results shows that, by precision fertilization, the maize yield was increased by nearly 10% and the fertilizer was saved about 10.5% compared with traditional fertilization mode.

7. CONCLUSION AND DISCUSSION

In this paper, spatial variation of soil nutrient was explored and we found that the spatial variability of P is the largest, which indicate that the precision fertilization of black soil area in Jilin province is dependent on the variability of P. We also analyzed the existing fertilization model and gave an

appropriate model fitted with black soil zone. A web-based expert system for precision fertilization was developed and the precision fertilization practice was implemented. The experiment shows that the adoption of above scheme acquired good results and achieved the aim of reducing cost, lessening environmental pollution, increasing yield and improving quality.

The later study will focus on the following aspects. Firstly, the current fertilization technology convergence is not enough, which should be strengthened. Secondly, the grid plotting is based on expert experience and the sampling number is not accurate, farther experiment should be done to achieve more optimum grid layout and more accurate grid number. Thirdly, the current precision fertilization is based on single variable, namely variable rate fertilizing P, in order to acquire more fertilization precision, dual variable rate fertilization should be considered, namely variable rate fertilizing P and N.

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PROBABILISTIC YIELD FORECAST BASED ON A PRODUCTION PROCESS MODEL

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Abstract: A method for probabilistic forecast of agricultural yield depending on meteorological variability, i.e. forecast of agrometeorological resources, is discussed. Forecast is based on the category of meteorologically possible yield (MPY)—the maximum possible yield for a given variety in the existing meteorological conditions. The forecasting process is realized by a potato production process model POMOD, which applies the principle of maximum plant productivity and method of reference yields. The yield diversity, granting probabilistic distribution was obtained from series of model calculations, whereby the weather realizations for post-forecast period were gained from a century-long meteorological data series. Three examples realized for extremely different years are discussed. The results of such forecast, presented as a cumulative distribution, allow user to adjust and plan activities to the sufficiently assured yield level. Forecast of agrometeorological resources can be transformed to the forecast of real commercial yield (CY) by incorporating the efficiency coefficient of using meteorological conditions (CY/MPY).

Keywords: probabilistic yield forecast, agrometeorological resources, crop modelling, yield categories, potato

1. INTRODUCTION

As widely acknowledged, probabilistic weather forecasts have essential advantages compared to the categorical ones, providing users with a

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potential range of weather-related risks and benefits. The same holds true for the prognosis in agricultural meteorology. By nature, the yield of agricultural crop is indefinite before its maturity, and the degree of this indefiniteness is mostly determined by the time interval of undefined environmental conditions and their site-specific variability. Not surprisingly, in agricultural meteorology probabilistic relationships between crop yield and environmental conditions are long since studied. For instance, distributions and cumulative distributions of agrometeorological factors have been determined in several agrometeorological handbooks (e.g. [Agroclimatic ... , 1974](#)). Probabilistic relationships of yield with solar radiation accumulation and water conditions were investigated by Tooming and Kõiva ([1979](#)). In nineteen eighties, the probabilistic approach to the agrometeorological yield forecast was introduced by Zhukovsky and Uskov ([1984](#)), Sepp ([1988](#)), Kuchar ([1989](#)), more accurately and concisely this method was defined in the common publications of Zhukovsky, Sepp and Tooming ([Zhukovsky et al., 1989, 1990](#)).

The principle of probabilistic yield forecast is to calculate crop production, using real meteorological data up to the forecast moment and different weather realizations, assessed either by weather conditions of previous years ([Sepp, 1988](#); [Zhukovsky et al., 1989, 1990](#)), generated weather data ([Zhukovsky et al., 1992](#); [Dubrovsky et al., 2002](#)), or ensembles of seasonal weather forecasts ([Cantelaube and Terres. 2005](#); [Challinor et al. 2005](#)).

The aim of this investigation was to give a probabilistic yield forecast scheme depending on meteorological variability only, with other words a probabilistic forecast method for agrometeorological resources. To describe and calculate the separate influence of meteorological conditions to the yield, we need to exclude the impacts of soil, landscape or management. Such distinctions can be derived from the categories of the method of reference yields, introduced by Tooming ([1982, 1984, 1993](#)) and developed in ([Zhukovsky et al. 1989](#)). In the present paper, we describe the realization of the reference yields method into the probabilistic forecast of agrometeorological resources carried out on the basis of potato production model POMOD ([Sepp and Tooming 1991](#); [Kadaja and Tooming 2004](#)).

2. MATERIALS AND METHODS

Proceeding from the method of reference yields ([Tooming, 1982, 1984, 1993](#)), which is respectively based on the principle of maximum plant productivity ([Tooming, 1967, 1970](#)), the maximum production and yields are observed under different limiting factors divided into agroecological groups: in general into biological, meteorological, soil and agrotechnical groups. These groups are included in the model separately, step by step, starting

from optimal conditions for the plant community (Tooming, 1975, 1977, 1984, 1993, 1998; Zhukovskij et al. 1989; Sepp and Tooming 1991; Kadaja and Tooming, 2004). The main categories of reference yields are, in descending order, potential yield (PY), meteorologically possible yield (MPY) and commercial yield (CY) (Fig. 1). This set of yield categories gives us an ecologically based reference system for comparison and analysis of different yield values obtained from field trials as well as from model experiments. Additionally, each of these categories represents particular kind of ecological resources for plant growth expressed in yield units.

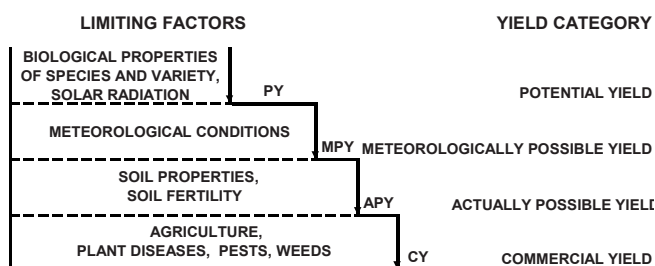


Figure 3. Hierarchy of reference yields, and limiting factors taken into account in each

The PY is determined by the biological properties of the species and variety and radiation resources available for utilisation. This yield category practically expresses the solar radiation resources for cultivating a given variety in yield units. The MPY, the main subject of interest in this study, is the maximum yield conceivable under the existing irradiance and meteorological conditions with optimal soil fertility and agrotechnology. MPY expresses agrometeorological resources, its mean value over a long period characterises agroclimatic resources in yield units. PPY is the maximum yield achievable under the existing meteorological and soil conditions, if soil tilling is optimal, the influence of plant diseases, pests and weeds is absent. CY is the yield attainable under existing farm conditions, if all the factors limiting the production process are taken into account.

In the frames of reference yields, the ratio CY/MPY is referred as efficiency coefficient of using meteorological conditions, characterizing which part of agrometeorological or agroclimatic resources is really used in existing soil and agricultural conditions.

In this work, the probabilistic yield forecast is realised on the basis of potato production model POMOD (Sepp and Tooming, 1991; Kadaja and Tooming, 2004), developed for computation of PY and MPY. The model is parameterised for late variety Anti based on the field experiments at Saku

(N 59°17'; E 24°37') in 2001–2004 (Kadaja, 2004) and at Kuusiku (N 58°59'; E 24°42') in 2005–2007.

Meteorological datasets of Tartu-Tõravere station (up to 1996 adjacent to Tartu N 58°18'00" E 26°43'48", from 1997 at Tõravere N 58°15'50", E 26°27'42'') from 1901 to 2007 are used as meteorological realizations. Daily data of temperature, precipitation and global radiation were used. As direct measurements of global radiation exist only since 1954, missing daily sums were calculated from sunshine duration, using regression equations established separately for every month. The beginning of growing period in spring is determined by the permanent rise of temperature above 8 °C or the fall of soil moisture below field capacity, the end in autumn by the permanent drop of temperature below 7°C or by the first night-frost $\leq -2^{\circ}\text{C}$. The data of soil water status in spring were collected from the reports of agrometeorological network. For the earlier period (up to the end of the 1940s) and for some last years when the agrometeorological network was not working, the fall of soil moisture below field capacity was derived on the basis of meteorological data at the stations. Hydrological parameters of Albeluvisol (WRB), sandy silt loam, the soil prevalent for the locality were applied (Kitse, 1978).

In this example we calculated and analyzed probabilistic forecasts for three years: a well balanced 2007, a dry 2006 and a wet and gloomy 1998. We observed four forecast dates, the last days of May, June, July and August.

3. RESULTS AND DISCUSSION

The time series of meteorologically possible yield (Fig. 2a) do not have any statistically significant trend for the period 1901–2007. Therefore, the distribution of MPY can be interpreted as climatic probabilistic yield forecast given before sowing date for the observed location. The probabilistic forecast is well illustratable by cumulative distribution giving maximum probability to the smallest (it is the most highly assured yield) and minimum probability to the highest yield (Fig. 2b). Uncertainty of probabilistic forecast depends on the number of weather realizations N . Probability, that the yield under prediction will be outside the computed limits is $1/N$, with probability $1/2N$ lower than the smallest yield value from the calculations and with probability $1/2N$ higher than the highest. Therefore, the uncertainty of the climatic probabilistic forecast in case of 107 different realizations is 0.94%, i.e. in future the MPY with a probability 0.0047 can be expected below and with the same probability above the limits presented by the cumulative distribution curve on Fig. 2b.

The climatic probabilistic forecast of the MPY is not symmetric in Tartu. Average of the yield series is 55.6 Mg ha^{-1} , median of the distribution is

58.6Mg ha⁻¹. The MPY values slightly above average are prevalent, while the highest MPY values corresponding to the near ideal meteorological conditions are quite rare. Span of yields below median is markedly wider than these of above. The lowest yields in the series below 30 Mg ha⁻¹ are related to excessively wet years, 1928, 1985 and 1998, whereas the MPY values between 30 and 40 Mg ha⁻¹ are mostly affected by dry conditions. Primarily, the climatic probabilistic yield forecast is a characteristic of the location, allowing comparing different regions for their favourableness and risks for growing a crop or variety in the long-time perspective.

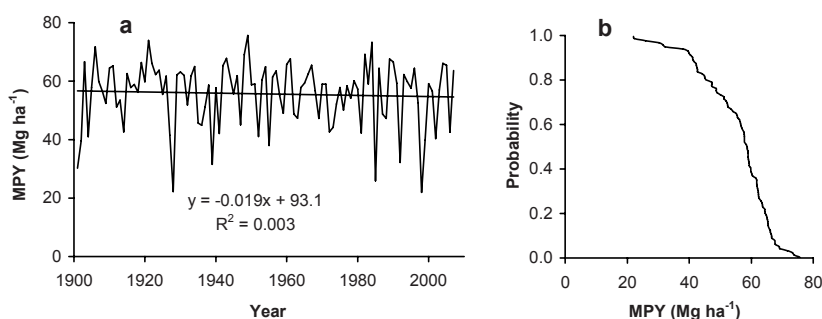


Figure 4. Time series of meteorologically possible yield from 1901 to 2007 (a) and its cumulative distribution – climatic probabilistic forecast of MPY (b)

In particular computations of probabilistic forecasts for 1998, 2006 and 2007, only the meteorological data of previous years were used, therefore the numbers of realisations are 97, 105 and 106, respectively.

The year 1998 was extremely wet in Tartu region, resulting in the lowest MPY of the last century. The forecast at the end of May, having yet quite good conditions for potato, did not contain any realizations in the ensemble matching to the final MPY of the year (Fig 3). The predictability of so low yield was across the limits of uncertainty then, less than 0.51%. The next month, June, was extra wet with precipitation exceeding the normal 2.7 times. The MPY values of computed ensemble decrease markedly to the end of June (Fig. 3) and yields assured with 80–90% probability are nearly two times lower than forecasted at the end of May (Fig. 4). Probability to get the yield equal to the final MPY was about 2% at the end of June. Two following forecasts reflect further worsening of the conditions during July and August, contributing to the excess water by 50% above normal precipitation. At the end of July, the final poor yield level or below it was predicted with 20% probability. At the end of August the forecast gave predominantly slightly lower yields than the final MPY, i.e. in September the very bad meteorological conditions of the summer were a little adjusted.

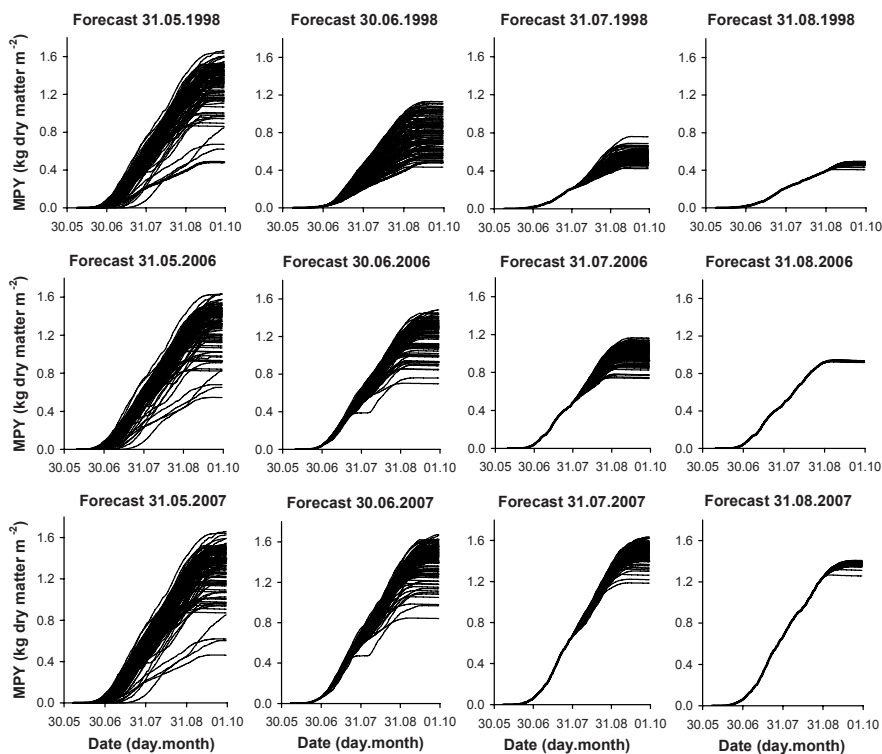


Figure 3. Ensembles of yield accumulation trajectories computed at different forecast dates for excessively wet 1998, droughty 2006 and quite well balanced 2007 years. Thick line indicates the yield accumulation computed by the data of forecasted year

In 2006 the shift of forecasts to the lower yields from month to month is caused by dry conditions having the strongest impact in July (Fig. 4). In 2007, the forecasts indicate improving yield promise up to the end of July due to fall-off probabilities for low yields. However, the dry and warm weather at the first half of August did not allow a peak of yield series in this year, removing higher realizations from the forecast ensemble already at the end of August.

Comparison of the forecast ensembles from the end of May of different years (Fig 3), and the corresponding cumulative distributions (Fig. 4) indicates that the forecasts from this date are quite similar, predicting slightly higher yields than climatic forecast in observed years. At the end of May, the span of yields is in average only 6% narrower than the range of climatic forecast certifying that such an early prediction does not improve the climatic forecast sufficiently. By the end of June the predicted range of yield decreases by 1.5 times, and three times by the end of July. The predictability qualifies quite highly in the last date. Although the tubers mass

mostly accumulates in August, the general condition of plants is sufficiently determined in July. By the end of August the range of predicted yields has decreased approximately 30 times in average, but usually for this time the growing period is almost over and September does not add much increase.

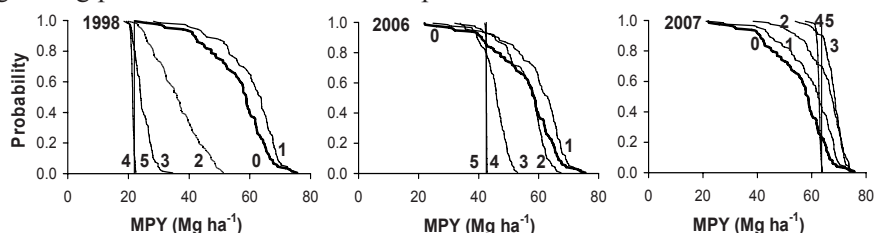


Figure 4. Probabilistic forecasts of meteorologically possible yield of potato at four forecast dates for 1998, 2006 and 2007 years, completed with climatic probabilistic yield forecast and the final MPY of the particular year

0 – Climatic forecast, 1 – 31. May, 2 – 30. June, 3 – 31. July, 4 – 31. August, 5 – Final yield

On this basis, the prediction of real yield in production, or commercial yield (CY), is realizable, by applying efficiency coefficient of utilizing meteorological resources (EUM). EUM is computable as the ratio between CY and MPY from previous years. Certainly, the spatial aspect must be assured – to give a forecast for a certain area, both the determined CY and calculated MPY must either correspond to the same location (e.g. field), or be the spatial means from given area (e.g. district, state). If actual CY values are available for a prolonged period, the trend in the series of EUM is convenient to calculate its value for the forecast year.

ACKNOWLEDGEMENTS

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POTATO PRODUCTION AS AFFECTED BY CROP PARAMETERS AND METEOROLOGICAL ELEMENTS

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Abstract: Meteorological elements directly influence crop potential productivity, regulating its transpiration, photosynthesis, and respiration processes in such a way as to control the growth and development of the plants throughout their physiological mechanisms at a given site. The interaction of the meteorological factors with crop responses is complex and has been the target of attention of many researchers from all over the world. There is currently a great deal of interest in estimating crop productivity as a function of climate by means of different crop weather models in order to help growers choose planting locations and timing to produce high yields with good tuber quality under site-specific atmospheric conditions. In this manuscript an agrometeorological model based on maximum carbon dioxide assimilation rates for C3 plants, fraction of photosynthetically active radiation, air temperature, photoperiod duration, and crop parameters is assessed as to its performance under tropical conditions. Crop parameters include leaf area and harvest indexes, dry matter content of potato tubers, and crop cycles to estimate potato potential yields. Productivity obtained with the cultivar Itararé, grown with adequate soil water supply conditions at four different sites in the State of São Paulo (Itararé, Piracicaba, Tatuí, and São Manuel), Brazil, were used to test the model. The results showed that the agrometeorological model tested under the climatic conditions of the State of São Paulo in general underestimated irrigated potato yield by less than 10%. This justifies the recommendation to test the performance of the model in study in other climatic regions for different crops and genotypes under optimal irrigation conditions in further scientific investigations. We reached the conclusion that the agrometeorological model taking into account information on leaf area index, photoperiod duration, photosynthetically active radiation and air

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temperature is feasible to estimate potential tuber yield at a commercial scale. The performance test shows that it can then be used to forecast harvest time, and also as an effective tool to predict the suitability of potential regions to the cultivation of potato crop, cultivar Itaráré, at the State of São Paulo, Brazil.

Keywords: modeling, *Solanum tuberosum* L., climate, crop indexes, tuber yield

1. INTRODUCTION

We considered potential yield to be the maximum possible yield of a given species or cultivar achievable under the existing conditions of solar radiation flux density, with all the other environmental factors considered to be optimal. Therefore, the potential yield is determined by the biological properties of the cultivar and radiation resources available. Potential yield expresses the solar radiation resources for cultivating a given genotype in yield units, whereas the commercial yield is the yield attainable under existing farm conditions that takes into account all the factors limiting the production process and the crop yield.

Meteorological factors directly influence potential crop productivity, regulating its transpiration, photosynthesis, and respiration processes in such a way as to control the growth and development of the plants throughout their physiological mechanisms at a given site. The interaction of the meteorological factors with the crop responses is complex. However, by assessing physiological crop responses to environmental factors under field conditions it is possible to derive mathematical models to estimate crop potential production as a function of climatic variables with a good precision.

Research has been conducted to quantify the effects of the environment on growth, development, and yield of many agronomic crops. Among the main environmental factors that strongly govern all physiological processes of the plants are global solar radiation flux density, air temperature, and available soil water content (Coelho and Dale, 1980).

Potato yield improvements can be obtained by increasing the net daily photosynthetically radiation (PAR) through higher solar irradiance or longer photoperiod (Stuttle et al., 1996). The photoperiod duration doubles from December to June at 50°N, while PAR increases eightfold from 2.11 to 17.01 MJ m⁻² day⁻¹ due to higher elevation of the sun above the horizon with lengthening days. Gross carbohydrate production on standard clear days increases from 108 to 529 kg ha⁻¹ day⁻¹ at 50°N, whereas it remains at about 420 kg ha⁻¹ day⁻¹ year-round near the equator. Low solar irradiance is a yield constraint at 30 to 40°N in fall and spring when potatoes are grown to escape the summer heat (Haverkort, 1990).

Sarquis et al. (1996) stated that the magnitude of the effect of elevated temperatures on potato growth and final yield is determined by an intricate interaction between soil temperature, air temperature, solar radiation flux density, and photoperiod duration. Their data extended previous observations of the reduction in photosynthesis rate under elevated temperatures (Midmore and Prange, 1992; Manrique and Bartholomew, 1991). Under field conditions reduced dioxide carbon assimilation could not explain the yield reduction observed; the temperature effect on assimilation was not as dramatic as it was on growth or yield. Other workers have reported a severe reduction in the rate of assimilation at air temperatures above 30°C under controlled experimental conditions. In such cases, reductions in CO₂ assimilation rate were shown to correlate well with reductions in growth and yield (Ku et al., 1977; Midmore and Prange, 1992). These results reveal the complexity of plant responses to the combined effects of water and temperature stress, which inevitably occur in association under field conditions (Pereira and Shock, 2006).

Knowledge of climatic requirements of potato and its physiological responses to the environment is extremely important to help growers produce high yields with good tuber quality under site-specific atmospheric conditions. The SUBSTOR-Potato crop soil weather model takes into consideration daily air temperature, photoperiod, intercepted solar radiation, soil water and nitrogen supply. The model simulated fresh tuber yields ranging from 4 t ha⁻¹ to 56 t ha⁻¹ due to differences in weather patterns, soils, cultivars, and management practices (Bowen, 2003).

Kadaja and Tooming (2004) proposed a relatively simple model POMOD to calculate potato yield, which permits integration of the knowledge in different disciplines on the potato crop yield levels, using the measured physiological, ecological, agrometeorological, and agronomical parameters of the plant. The input variables of the model can be divided into four groups: daily meteorological information, annual information, location, and cultivar. The first group includes global radiation, air temperature, and precipitation. The location is characterized by geographical latitude and hydrological parameters. As to cultivar, the parameters of gross and net photosynthesis, the coefficients of growth and maintenance respiration, and albedo of the crop are also needed.

The LINTUL-POTATO simulation model (Kooman and Haverkort, 1995) establishes potential yield of a certain cultivar for a determined growing period and plant density, and is based on incident photosynthetically active radiation (PAR), the fraction of PAR intercepted by the crop, and radiation use efficiency to produce dry matter. Phenological crop development is driven by accumulated degree-days, while development stage determines dry matter partitioning and the pattern of intercepted PAR is defined through

growth. The potential yield established with this simulation model was used by Caldiz and Struit (1999) to perform a preliminary yield gap analysis regarding actual and attainable potato yield in different areas of Argentina.

We tested the performance of a model based on studies of maximum rates of carbon dioxide assimilation for a C3 crop as a function of air temperature, a fraction of global solar radiation flux density (PAR), photoperiod duration, and leaf area index to estimate the potential productivity of potato. In order to assess the performance of the proposed mathematical model, the estimated values of tuber yield were compared to observed productivity data under irrigation conditions for the studied sites. The present study was similar to the potential productivity estimation model described by Villa Nova et al. (2001) and employed by Villa Nova et al. (2005) for sugar cane in Piracicaba, SP, Brazil.

2. MATERIAL AND METHODS

The proposed model for the estimation of potato potential yield (EPY, t ha⁻¹), expressed by equation 1, is based upon the concept that the maximum rate of dioxide carbon assimilation by the plants for production of carbohydrate (CH₂O) is related to the active photosynthetically fraction of the solar spectrum (PAR) and air temperature:

$$EPY = 1.27 \cdot 10^{-6} \cdot CDA \cdot LAI \cdot GS \cdot N \cdot C(LAI) \cdot C(T) \cdot HI \cdot 100 / DM \quad (1)$$

where CDA is the carbon dioxide assimilation rate (μL cm⁻² h⁻¹), LAI is the maximum leaf area index, GS is the number of days of the crop growing season, N is the mean photoperiod or day length duration throughout of the crop growing season (hours), C(LAI) is the correction factor for leaf area index variation over time, C(T) is the correction factor for maintenance respiration, HI is the harvest index, and DM is the dry matter content of the potato tubers (%).

Making use of the Clausius-Clapeyron's equation with the masses of CO₂ equal to 44 g mol⁻¹ and of CH₂O corresponding to 30 g mol⁻¹, and considering 1 μL of CO₂ at 15°C (288 K) and 1 atmosphere equal to 1.863 * 10⁻⁶ g CO₂, one can infer that the CH₂O/CO₂ ratio assumes a value of 1.27 * 10⁻⁶ of g CH₂O/μL CO₂ (Villa Nova et al., 2001).

Applying the necessary corrections to the aforementioned equation in order to express the estimates of potato potential yield in tons per hectare per crop cycle, we have:

$$EPY = 1.27 \cdot 10^{-4} \cdot CDA \cdot LAI \cdot GS \cdot N \cdot C(LAI) \cdot C(T) \cdot HI \cdot 100 / DM \quad (2)$$

Without considering HI, the product of the other terms of the equation 2 depicts the estimation of the total dry matter produced by the potato plants, including roots, leaves and shoots.

Plotted and interpolated values of CDA were obtained from a graph that shows the relation between air temperature and maximum rate of CO₂ assimilation for a C3 crop species under controlled conditions (Heemst, 1986) as a function of the ambient temperature (T) and photosynthetically active radiation (PAR). However, under field conditions where plants are subjected to fluctuating temperature conditions, there appears to be adaptation of the photosynthetic apparatus. Thus, such plotted and interpolated CDA data are described mathematically by the following equation (Penning de Vries et al., 1989):

$$CDA = CDA_{\max} \left[1 - e^{\frac{-0.5 \cdot PAR}{CDA_{\max}}} \right] \quad (3)$$

where CDA_{max} is the maximum carbon dioxide assimilation rate of 48 μL cm⁻² h⁻¹.

The photosynthetically active radiation (PAR), expressed in Joule m⁻² s⁻¹, was calculated by the equation proposed by Assunção (1994) as a function of the global solar radiation flux density and insolation ratio:

$$PAR = \frac{Qg}{3600 \cdot N} * \left[0.5 - 0.1 * \frac{n}{N} \right] \quad (4)$$

where Qg is the mean global solar radiation flux density throughout the crop growing season (Joule m⁻² day⁻¹), N is the mean photoperiod during the crop cycle (hours), and n/N is the actual mean insolation ratio of the period.

The global solar radiation flux density (Qg) was estimated taking into account the mean values of a and b Angstrom's coefficients obtained by Cervellini et al. (1966) for the State of São Paulo, Brazil. The equation used for the sites where no radiometric measurements were available for the current study was the following:

$$Qg = Qo \left[0.24 + 0.58 * \frac{n}{N} \right] \quad (5)$$

where Qo is the extra-terrestrial radiation, expressed in Joule m⁻² day⁻¹, having been determined by the expression below:

$$Qo = 38.32 * 10^6 \left[h * \sin \delta * \sin \varphi + \cos \delta * \cos \varphi * \sin H \right] \quad (6)$$

where 38.32 * 10⁶ is the mean value of corrected solar constant converted into Joule m⁻² day⁻¹, given by Crommelynck and Fichot (1997), H is the semi-arc from the meridian crossing of the sun to sunset in degrees, h is the diurnal semi-arc in radians, δ is the solar declination in degrees, and φ is the local latitude in degrees.

The equations that defined δ , H , and N (Pereira et al., 2003) were:

$$\delta = 23.45 * \sin \left[\frac{360}{365} * (DJ - 80) \right] \quad (7)$$

where DJ is the number of days since the first day of January up to the considered date.

$$H = \arccos \left[-\tan \delta * \tan \varphi \right] \quad (8)$$

$$N = \frac{2 * H}{15} \quad (9)$$

The number of hours of insolation (n) was measured with a Campbell-Stokes sunshine recorder installed at the four weather stations where the studies were carried out.

All the meteorological data used as input variables of the potato potential yield model were obtained from conventional weather stations set up at research locations of the Agronomic Institute of Campinas, IAC, University of São Paulo, ESALQ/USP, and State University of São Paulo, FCA/UNESP. These governmental Institutions of the State of São Paulo provided the necessary meteorological data for the municipalities of Itararé, Tatuí, Piracicaba, and São Manuel, SP, Brazil.

The climate of Tatuí (23o22'S, 47o52'W Gr., and 600m), Piracicaba (22o43'S, 47o25'W Gr., and 580m), and São Manuel (22o44'S, 48o34'W Gr., and 700m) is classified as Cwa or sub-tropical with rains in the summer and dry winter, according to the Köppen System. The climate of Itararé city (24o06'S, 49o20'W Gr., and 1150m) in the State of São Paulo, Brazil, is classified as Cfb or rainy temperate of altitude, constantly wet throughout the year.

The values of $C(T)$ equal to 0.6 and 0.5 were adopted, whenever the mean air temperatures throughout the crop-growing season were below or above 20oC, respectively, as recommended by Doorenbos and Kassam (1979). The value of $C(LAI)$ was calculated by the equation described by Villa Nova et al. (2001) as follows:

$$C(LAI) = \frac{1 - e^{-0.8 * LAI}}{2} \quad (10)$$

The ratio between harvested yield and net total dry matter is given by the harvest index (HI) for high-producing cultivars under irrigation. For potato, whose commercial product is the tuber, HI varies from 0.55 to 0.65 (Doorenbos and Kassam, 1979). For practical purposes, we adopted the mean value corresponding to 0.6 to calculate the final crop production.

The maximum leaf area index (LAI) for the cultivar Itararé (IAC-5986) was determined experimentally in the field by Varillas (1991) and Robles (2003) under the climatic conditions of Itararé and Piracicaba.

The dry matter content of the tubers is intimately related to the tuber specific gravity. To measure tuber specific gravity the weight-in-air/weight-in-water method was used. For that, a random sample of tubers was first weighed in air (W_{air}) and, after submerging the tubers in water, weighed again (W_{water}). Thus, specific gravity (SG) was calculated using the following formula (Stark and Love, 2003):

$$SG = \frac{W_{air}}{W_{air} - W_{water}} \quad (11)$$

Dry matter content of the tubers in percentage, was determined by the expression described by Ramos (1999) as a function of the specific gravity as follows:

$$DM = 24.182 + 211.04 * [SG - 1.0988] \quad (12)$$

The calculated values of the potential yield obtained by the proposed method were correlated with the observed data from the production fields. Since the coefficients of correlation and determination are not always suitable to evaluate the performance of a model, the agreement index d was also used (Willmott et al., 1985). The index c proposed by Camargo and Sentelhas (1995) was also adopted in this paper to indicate the performance of the model, putting together the accuracy R and the exactness d indices, being defined as the product of both indices.

The values of the tuber specific gravity and dry matter content were obtained by the researchers from the Agronomic Institute of Campinas – IAC – at all the locations where the potato experiments were conducted from 1985 to 2005 (data not published).

3. RESULTS AND DISCUSSION

Potato potential yield for the cultivar Itararé was calculated throughout fifteen site-years at four different regions of the State of São Paulo, Brazil (Tables 1 and 2) using of the mean values of global solar radiation flux density, photoperiod duration, photosynthetically active radiation, air temperature, and the maximum rates of carbon dioxide assimilation obtained from equation 3, which are the required input variables of the proposed model.

Tuber potential yields calculated by the agrometeorological model in study and potential yields harvested from the production fields were highly correlated, since the statistical analysis shows that over 92% of the potential yield variations can be explained by the calculated values. The corresponding values of fresh tuber yields estimated by the model varied

from 16.8 to 35.7 t ha⁻¹, whereas those of fresh tuber yields obtained from the production areas with an adequate soil water supply were within the range varying from 17.5 to 39.0 t ha⁻¹ (Table 2). The larger difference between measured and estimated tuber yield was observed for the growing period September through January of the years 1998 and 2003, when the model slightly underestimated and overestimated potential yield at 3.3 and 3.5 t ha⁻¹, respectively.

Table 1. Meteorological data throughout different years and growth periods of the potato crop, cultivar Itararé (IAC-5986), grown at Itararé, Tatuí, Piracicaba, and São Manuel, State of São Paulo, Brazil.

Site	Year	Growth period	Cycle (days)	T (oC)	n/N	Q _g (J m ⁻² s ⁻¹)	PAR (J m ⁻² s ⁻¹)	P (mm)
Itararé	1985	Mar./Jun.	100	16.5	0.57	395.0	176.3	587
	1993	Sep./Jan.	137	18.0	0.45	429.8	194.4	809
	1994	Mar./Jul.	114	16.0	0.54	382.5	170.0	572
	1997	Feb./Jul.	140	16.5	0.57	411.0	181.1	596
	1998	Apr./Aug.	112	15.0	0.57	378.3	167.9	505
	1998	Sep./Jan.	117	18.0	0.33	372.0	173.5	1163
	1999	Mar./Jul.	126	15.6	0.55	388.0	172.8	578
	2000	Nov./Mar.	133	20.2	0.49	452.1	204.1	818
	2001	Mar./Jul.	102	16.9	0.55	392.2	173.5	549
	2003	Sep./Jan.	98	17.5	0.43	415.9	188.8	865
	2005	Mar./Jul.	133	16.7	0.58	400.6	177.0	508
Tatuí	2005	Oct./Feb.	122	18.7	0.41	413.8	190.2	935
	2001	Sep./Jan.	115	22.8	0.55	480.0	212.5	723
Piracicaba	1989	Oct./Feb.	105	23.6	0.58	503.0	222.2	759
S. Manuel	2000	Aug./Jan.	131	14.8	0.56	380.4	168.6	813

T = daily air temperature; *n/N* = insolation ratio; *Q_g* = global solar radiation density flux; and *PAR* = photosynthetically active radiation; *P* = total of rainfall throughout the crop growing season. Monthly average values.

Table 2. Cultivar characteristics throughout different years and growth periods of the potato crop, cultivar Itararé (IAC-5986), grown at Itararé, Tatuí, Piracicaba, and São Manuel, State of São Paulo, Brazil, and the respective potential yield data.

Site	Year	Growthperiod	CDA	LAI	C(LAI)	C(T)	HI	DM	EPY	MPY
Itararé	1985	Mar./Jun.	41.0	4.34	0.480	0.6	0.6	25.0	17.5	17.5
	1993	Sept./Jan.	41.5	4.34	0.480	0.6	0.6	25.0	27.9	26.4
	1994	Mar./Jul.	41.0	4.34	0.480	0.6	0.6	17.8	27.8	28.2
	1997	Feb./Jul.	41.0	4.34	0.480	0.6	0.6	18.9	32.9	30.8
	1998	Apr./Aug.	41.0	4.34	0.480	0.6	0.6	22.3	21.4	20.3
	1998	Sep./Jan.	41.0	4.34	0.480	0.6	0.6	16.5	35.7	39.0
	1999	Mar./Jul.	41.0	4.34	0.480	0.6	0.6	17.8	30.7	31.6
	2000	Nov./Mar.	42.0	4.34	0.480	0.5	0.6	18.0	32.0	31.5
	2001	Mar./Jul.	41.0	4.34	0.480	0.6	0.6	22.3	19.8	19.5
	2003	Sep./Jan.	41.5	4.34	0.480	0.6	0.6	16.8	29.7	26.2
	2005	Mar./Jul.	41.0	4.34	0.480	0.6	0.6	22.3	25.9	25.2
Tatuí	2005	Oct./Feb.	41.5	4.34	0.480	0.6	0.6	19.7	32.0	32.7
	2001	Sep./Jan.	46.7	4.34	0.480	0.5	0.6	17.8	30.9	29.2
Piracicaba	1989	Oct./Feb.	47.7	2.50	0.423	0.5	0.6	16.0	16.8	18.0
S. Manuel	2000	Aug./Jan.	40.7	4.34	0.480	0.6	0.6	16.0	32.0	33.1

CDA = Carbon dioxide assimilation maximum rates ($\mu\text{L cm}^{-2} \text{ h}^{-1}$); *LAI* = leaf area index (maximum value); *C(LAI)* = correction factor for leaf area index variation; *C(T)* = correction factor for maintenance respiration; *HI* = harvest index; *DM* = dry matter content (%); *EPY* = estimated crop potential yield (t ha^{-1}); *MPY* = measured crop potential yield (t ha^{-1}).

In the most important potato production areas of Argentina, Caldiz and Struit (1999) reported that actual fresh tuber yields vary from 13 to 30 t ha^{-1} , whereas potential yields estimated by the LINTUL-POTATO simulation model ranged from 47 to 126 t ha^{-1} . Differences between actual and potential yield might be attributed to suboptimal solar radiation interception by the foliage, cultivar, seed management, physiological age of the seed, suboptimal management of water and fertilizer, and inadequate control measures for early blight and late blight.

The potential yield of agronomic crops is dramatically affected by the amount of water applied during the crop-growing season at a given region. Water and temperature are important climatic factors to consider in crop modelling studies. Cooler temperatures result in delayed maturity, which provides more time for the interception of solar radiation and conversion of intercepted radiation into dry matter. Stark and Love (2003) point out that two major factors influence tuber yield: a) photosynthetic activity and duration of the leaf canopy, and b) the length of the linear tuber growth phase. The longer a canopy is able to produce photosynthate at a relatively high rate, and the longer tubers are bulking at their maximum rate, the higher the yield will be in such a way as to express the productive potentiality of potato crop at a given site.

As to the effect of water application on the productive potentiality expression of potato in a determined climatic locality, Bowen (2003) reported that a reduction of only 62 mm in water applied resulted in a decrease in fresh tuber yield from 38.2 to 30.3 t ha^{-1} . For the summer potato crop, applied water ranged from 380 to 584 mm and the associated yields ranged from 12.1 to 25.4 t ha^{-1} . Therefore, about half as much water was used during the winter to produce 150% more yield than was obtained throughout the summer crop-growing season.

The differences observed on the dry matter content throughout different years and growth periods of the potato crop (Table 2) might be ascribed to climatic variations on tuber specific gravity. Apart from the primary environmental factors affecting specific gravity of irrigated potatoes (air and soil temperatures), other weather conditions can also affect tuber specific gravity.

Stark and Love (2003) state that high evaporative demand caused by low relative humidity, high global solar radiation flux density, and/or high wind speed can reduce photosynthesis by causing stomata to close with an accompanying restriction of CO_2 uptake. Prolonged periods with overcast

skies can also reduce light intensity to levels below that required for maximum dry matter production.

The coefficient of determination R^2 and correlation R bring information about the degree of accuracy, but do not reveal the exactness of the model. The index of agreement d equal to 0.981 reveals a high level of exactness. The index c was 0.945 for the studied sites, showing an excellent model performance, according to the interpretation reported by Camargo and Sentelhas (1995). Both the model accuracy, given by the trend line, and the model exactness shown by the dispersion of the data around the fitted 1:1 line, were outstanding (Figure 1). The value of c was higher than 0.93, exceeding, therefore, the values of d considered as satisfactory. The lower limit for the index c recommended by Robinson and Hubbard (1990) is 0.75.

The results showed that the agrometeorological model tested under the climatic conditions of the State of São Paulo, Brazil, in general underestimated irrigated potato yield by less than 10%. This justifies the recommendation to test the performance of the model in other climatic regions, for different crops and genotypes under optimal irrigation conditions in further scientific investigations.

Given the excellent performance of the model we suggest that it can be used to forecast harvest time, or be used as an effective tool to predict the suitability of potential regions to the cultivation of potato crops, cultivar Itararé (IAC-5986), in the State of São Paulo, Brazil.

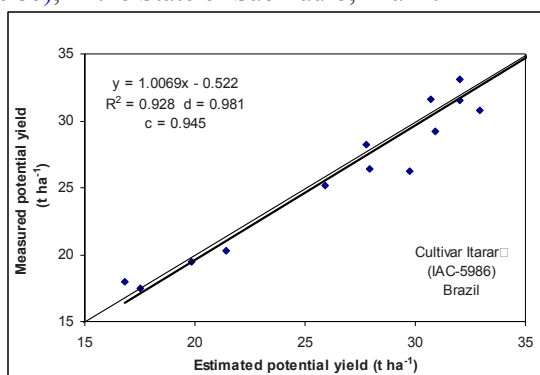


Fig. 1. Relation between observed and predicted potential potato tuber yield, cultivar Itararé (IAC-5986), for the State of São Paulo, Brazil.

4. CONCLUSIONS

The agrometeorological model taking into account information on leaf area index, photoperiod duration, photosynthetically active radiation and air temperature is feasible to estimate potential tuber yield at a commercial scale.

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REGRESSION MODELS FOR SAFFRON YIELDS IN IRAN

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Abstract: Saffron is an important crop in social and economical aspects in Khorassan Province (Northeast of Iran). In this research we tried to evaluate trends of saffron yield in recent years and to study the relationship between saffron yield and the climate change. A regression analysis was used to predict saffron yield based on 20 years of yield data in Birjand, Ghaen and Ferdows cities. Climatologically data for the same periods was provided by database of Khorassan Climatology Center. Climatologically data included temperature, rainfall, relative humidity and sunshine hours for Model I, and temperature and rainfall for Model II. The results showed the coefficients of determination for Birjand, Ferdows and Ghaen for Model I were 0.69, 0.50 and 0.81 respectively. Also coefficients of determination for the same cities for model II were 0.53, 0.50 and 0.72 respectively. Multiple regression analysis indicated that among weather variables, temperature was the key parameter for variation of saffron yield. It was concluded that increasing temperature at spring was the main cause of declined saffron yield during recent years across the province. Finally, yield trend was predicted for the last 5 years using time series analysis.

Keywords: saffron, crop weather model, yield

1. INTRODUCTION

Saffron is a plant with a wide ecological, physiological and phonological characterizes. As a result, there is a great deal of controversy related to ecological, phonological and standard type of climate suitable for this plant. In Iran saffron grows well under temperate and dry climates, its vegetative

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growth coincides with cold weather and freezing conditions. Usually the maximum temperature for October, November and December in the southern parts of Khorassan—the main saffron growing area of the Iran—does not exceed 20°C, while the minimum temperature reaches 0°C. The influence of weather variation has been determined for different crops in many parts of the world. Mashayekhi et al. (2006) assessed the effect of environmental temperature on flowering behavior of saffron. The results showed that mean and minimum temperature were the most important driving force to determine flower emergence and flower initiation in saffron, respectively. Behdani et al (2003) developed a model for saffron flowering time. Their aim was to develop a thermal model that can be used for prediction of saffron flowering time. They concluded that developing rate (DR) of saffron has a unique response to mean September temperature. Sanaeinejad et al (2007) studied the effect of meteorological factors on phenological stage of wheat in Iran. Results showed that, the most sensitive stages of wheat growth are anthesis, milky and waxy stages. Most researches considered the impact of weather on crop, but study of long-term trend for saffron yield using crop weather model is lacking in Iran. In this paper, we tried to evaluate the trends of saffron yield in recent years and study of relationship between saffron yield and climate variation for the main areas of Saffron cultivation in South Khorassan Province of Iran.

2. MATERIAL AND METHODS

2.1 Trend of saffron yield

In this study Data of Saffron yield in three main areas of cultivation in South Khorassan (Birjand, Ferdows and Ghaen) were collected. The data from 1983 to 2005 were provided by Khorassan Jahade-Agriculture Organization. Table 1 shows the average of long-term saffron yield in this period.

Table1. Average of saffron yield in area under study

City	Average of saffron yield (kg/ha)	Period	year
Birjand	5.66	21	1983-84 , 2003,04
Ferdows	5.16	22	1983-84 , 2004-05
Ghaen	5.61	17	1987-88 , 2003-04

Study of yield change trend was conducted on the basis of time series analysis. A time series is a sequence of observations which are ordered in time. If observations are made on some phenomenon throughout time, it is most sensible to display the data in the order in which they arose, particularly since successive observations will probably be dependent. Time series are best displayed in a scatter plot. The series value Y is plotted on the vertical axis and time t on the horizontal axis.

In time series the equations are showed in the linear and curvilinear forms (equations 1, 2 and 3).

$$Y_t = b_1 + e_t \quad (1)$$

$$Y_t = b_1 + b_2t + e_t \quad (2)$$

$$Y_t = b_1 + b_2t + b_3t^2 + e_t \quad (3)$$

In which:

Y_t : Variable value in each time t (here is, saffron yield per year)

b : Coefficients of model

e_t : Error of Y estimates in each year.

In this study, both linear and nonlinear (degree 2) function were properly fitted to yield data. Yield trend in time series, was predicted for 5 years after the last datum. In this study, for predicting trend of saffron yield exponential smoothing was used.

2.2 Evaluation of correlation between yield and weather indices

In order to determine relationship of saffron yield in areas under study, weather indices of about 20 years data including monthly rainfall, monthly average minimum temperature and average maximum temperature and average temperature, monthly average minimum and maximum relative humidity and monthly total of sunshine hour's were collected from database of Khorassan Climatology Center. In this research two models were used. For model I all of the top parameters and for model II temperature and rainfall were used. Relationship of yield to weather factors was determined by simple and multiple regressions. For this reason, at first, saffron yield (Y) was analyzed with monthly weather factor for all areas under study separately by regression in order to determine climatic indicator for each area and also to determine the most important month affecting saffron yield. Then, by multiple regressions, relation of saffron yield (Y) to climatic variable was determined for each area. The method used was Backward Stepwise Regression. Thus, the final model describing yield was calculated

by the most important climatic variables. For analysis time series the software Minitab, ver. 13.1 and for regression analysis JMP ver 4 were used.

3. RESULT AND DISCUSION

3.1 Trend of saffron yield

Trend of saffron yield for all areas under study were similar. So, trend of saffron yield followed second degree model. The equation of trend of saffron yield in Birjand, Ferdows and Ghaen are defined by equation 4, 5 and 6, respectively. Figure 1, 2 and 3 show trend of saffron yield for area under study.

Birjand:

$$Y = 5.56 + 0.23(t) - 0.016(t^2) \quad (4)$$

Ferdows:

$$Y = 5.81 + 0.12(t) - 0.012(t^2) \quad (5)$$

Ghaen:

$$Y = 4.57 + 0.51(t) - 0.034(t^2) \quad (6)$$

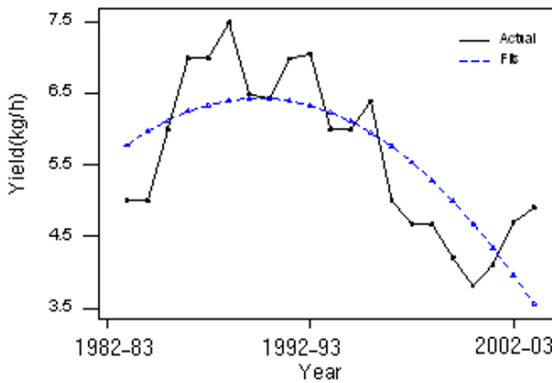


Figure 1. Trend analysis of saffron yield in Birjand.

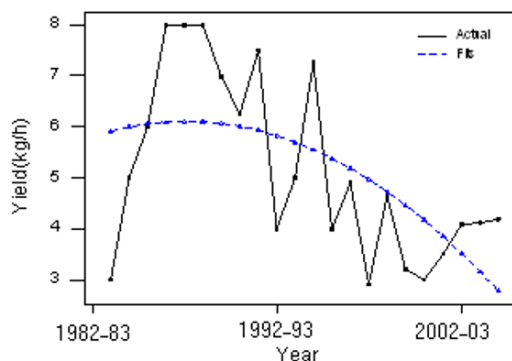


Figure 2. Trend analysis of saffron yield in Ferdows

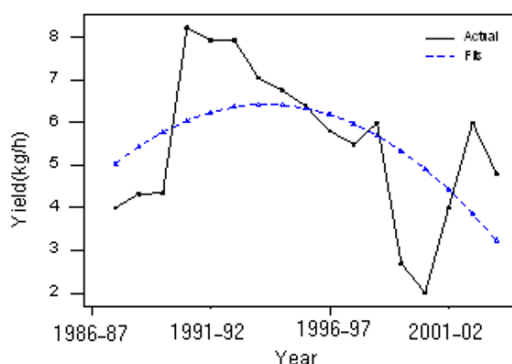


Figure 3. Trend analysis of saffron yield in Ghaen

Results show that there are two characteristic parts for this 20 years period. For the first 10 years we observed yield increase and at the second 10 years we observed yield reduction. Thus, the aim was to relate yield reduction to change of climatic indicators, to determine contribution of these factors affecting yield changes.

3.2 Relation of weather variability to saffron yield

3.2.1 Birjand

The Results of regression analysis among the yield at 21 years of Birjand and weather variability after omitting variables by stepwise technique showed that minimum and maximum temperature of April and sunshine hour's of Feb have significant effects on saffron yield variation for Birjand. Regression equations for two models are as follows:

$$Y = 15.27 - 0.02 \times (T_{avg-Apr}) - 0.53 \times (T_{min-Apr}) - 0.02 \times (Sun_{Feb}) \quad Model\text{I} \quad (7)$$

$$Y = 14.86 - 0.38 \times (T_{min-Apr}) - 0.22 \times (T_{max-Apr}) \quad Model\text{II} \quad (8)$$

Diagram of two variable regressions in model II is shown in figure 4. The observed and predicted model yields are shown in figure 5.

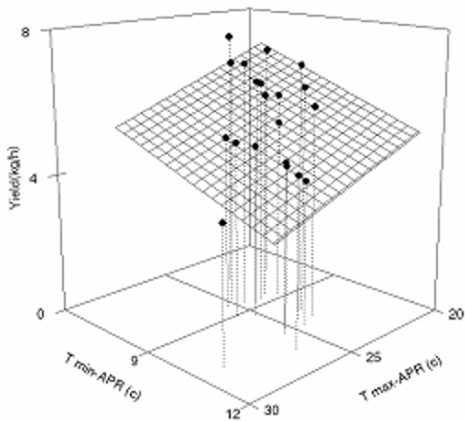


Figure 4. Effect of weather factors on saffron yield in Birjand

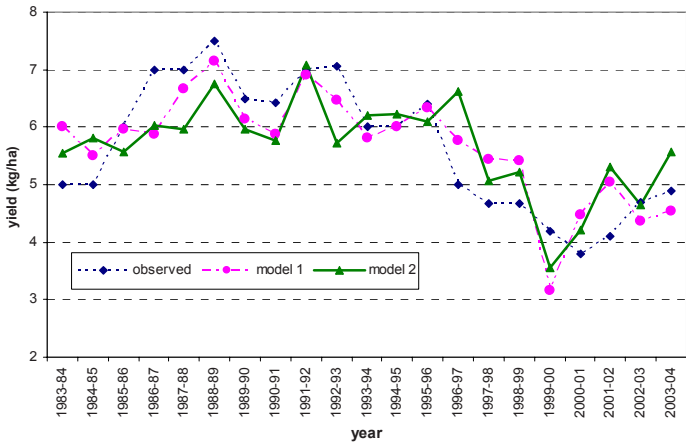


Figure 5. Observed and predicted saffron yield in Birjand.

3.2.2 Ferdows

Results for two models are similar for Ferdows. In Ferdows the most important factor was minimum temperature of April. The regression equation for yield and minimum temperature of April was as figure 6. Figure 7 shows the actual and predicted yield model in Ferdows.

$$Y = 16.88 - 1.1 \times (T_{\min_Apr}) \quad \text{Model II} \quad \& \quad \text{Model III} \quad (9)$$

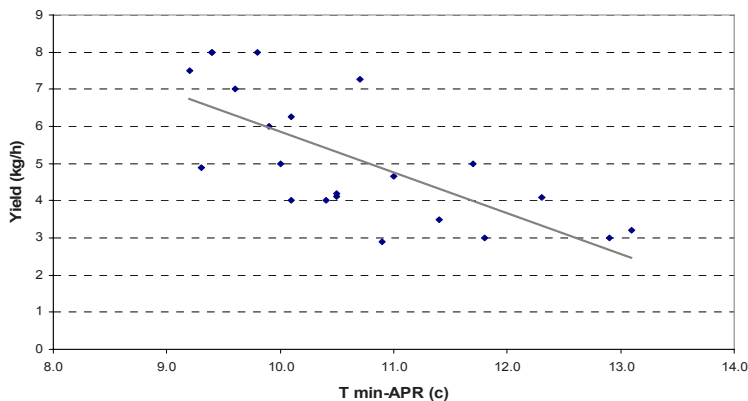


Figure 6. Effect of weather factor on saffron yield in Ferdows.

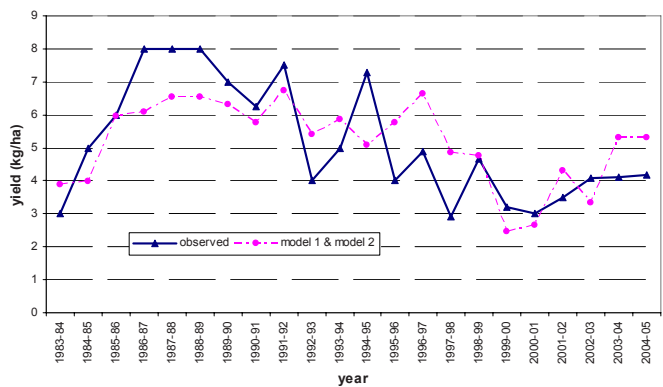


Figure 7. Observed and predicted saffron yield in Ferdows.

3.2.3 Ghaen

The results of two models For Ghaen were different. In model I maximum relative humidity of April and monthly total of sunshine hours of April and Mars and for model II maximum temperature of April and maximum and average temperature of March were important (equations 10 and 11). Also figure 8 shows the actual and predicted model yields in Ghaen. The predicted values did not differ much from those observed value.

$$Y = 13.87 + 0.07(R_{\max_Apr}) - 0.02(Sun_Mar) - 0.03(Sun_May) \quad \text{Model I} \quad (10)$$

$$Y = 21.76 + 1.14(T_{\text{avg}} - Mar) - 1.17(T_{\max} - Mar) - 0.42(T_{\max} - Apr) \quad \text{Model III} \quad (11)$$

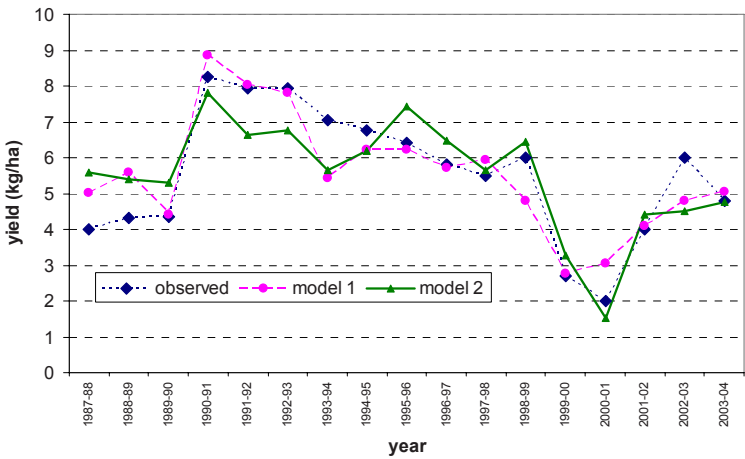


Figure 8. Observed and predicted saffron yield in Ghaen.

Table 2. The Equation and coefficients of determination for model I

CITY	EQUATION	R^2
Birjand	$Y = 15.27 - 0.02 \times (T_{avg-Apr}) - 0.53 \times (T_{min-Apr}) - 0.02 \times (Sun_{Feb})$	0.69
Ferdows	$Y = 16.88 - 1.1 \times (T_{min-Apr})$	0.50
Ghaen	$Y = 13.87 + 0.07(R_{max-Apr}) - 0.02(Sun_{Mar}) - 0.03(Sun_{May})$	0.81

Table 3. The Equation and coefficients of determination for model II

CITY	EQUATION	R^2
Birjand	$Y = 14.86 - 0.38 \times (T_{min-Apr}) - 0.22 \times (T_{max-Apr})$	0.53
Ferdows	$Y = 16.88 - 1.1 \times (T_{min-Apr})$	0.50
Ghaen	$Y = 21.76 + 1.14(T_{avg-Mar}) - 1.17(T_{max-Mar}) - 0.42(T_{max-Apr})$	0.72

Maximum coefficients of determination (R^2) were 0.81 and 0.72 for Ghaen in model I and model II respectively. Minimum coefficient of determination (R^2) were 0.50 for Ferdows. It means 50% of yield variation is described by weather factors. Finally, yield trend was predicted for the last 5 years after the last datum using time series analysis. These results showed in figures 9, 10, and 11. The trends of yield for the last 5 years for 3 cities are descending (redlines in figures).

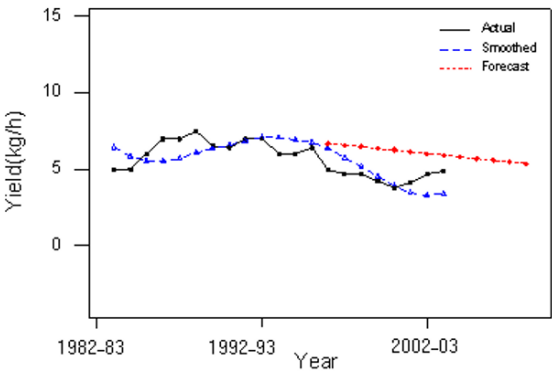


Figure 9. Trend of prediction of saffron yield in Birjand.

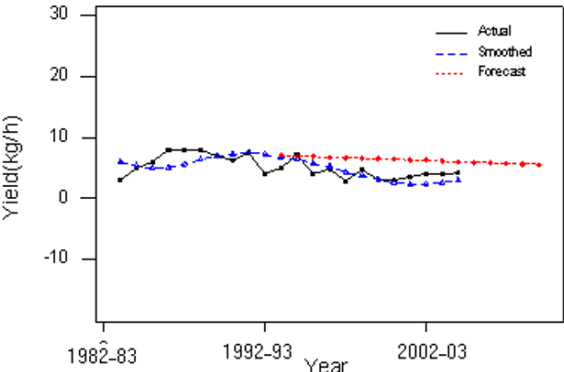


Figure 10. Trend of prediction of saffron yield in Ferdows.

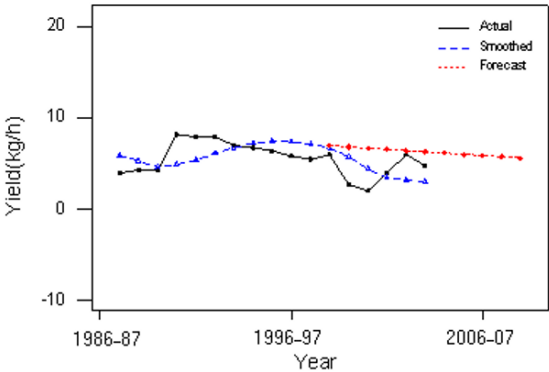


Figure 11. Trend of prediction of saffron yield in Ghaen.

4. CONCLUSION

The results showed that the models can predict saffron yield satisfactory and difference between actual and predicted yields were not considerable, especially in Ghaen and Birjand (figure 9, 10 and 11). The results of coefficients of determination showed that (R^2) for model I is higher than model II. Also findings showed that reduction of saffron yield in South khorasan Province during 10 years has been caused significantly by weather factors in spring month particularly temperature. It is concluded that temperature (maximum, minimum and average) of spring month (March and April) is very important and increasing trend in spring temperature was the main cause of declined saffron yield during recent years across the province. Rainfall, relative humidity and monthly total of sunshine hour's factors hold a less importance in yield saffron in regression analysis.

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GRAPSI_DRAW DIGITAL PSYCHROMETRIC CHART

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Abstract: Knowledge of psychrometric properties is the basic requirement for environmental measurements and drying processes. The software GRAPSI_DRAW is capable of calculating the psychrometric properties and simulating the basic psychrometric processes with the precision of analytical methods, also showing the results in charts plotted on the computer screen.

Keywords: psychrometry, engineering, graphical interface

1. INTRODUCTION

Psychrometry or hygrometry is the study of the thermodynamic properties of gas-vapor mixtures. Despite their numerous applications, psychrometric properties of the air are useful in heating, ventilating, air-conditioning, meteorology and grain storage (Zolnier, 1994).

A psychrometric chart is a graph of the physical properties of moist air at a constant atmospheric pressure. It expresses how various properties relate to each other, and is thus a graphical equation of state. The thermophysical properties

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found on most psychrometric charts are the dry bulb temperature, the wet bulb temperature, the dew point temperature, the relative humidity, the humidity ratio, the partial pressure, the saturation pressure, the enthalpy and the specific volume. The versatility of the psychrometric chart lies in the fact that by knowing two independent properties of some moist air, the other properties can be determined. The most widely used combinations are dry bulb temperature and relative humidity, dry and wet bulb temperatures and dry bulb and dew point temperatures (Navarro and Noyes, 2001; Wilhelm, 1976).

Since the atmosphere can be considered as a mixture of dry air and water vapor, at any given temperature, the pressure of the water vapor in the mixture can be any value equal to or less than the saturation pressure at that temperature. The vapor pressure is also called partial pressure and most often is used to describe the tendency of molecules and atoms to escape from a liquid or a solid. Saturation pressure corresponds to the pressure at which moist air starts boiling, at a given temperature. So, saturation pressure is the highest possible pressure at any given temperature (Brooker et al., 1992).

The dry bulb, wet bulb and dew point temperatures are important to determine the state of humid air. The dry bulb temperature is the most common used property of air. Its value refers basically to the ambient air and is measured by a normal thermometer freely exposed to the air but shielded from radiation and moisture (Zolnier, 1994). Wet bulb temperature is that of adiabatic saturation. This property is indicated by a moistened thermometer bulb exposed to the airflow. The adiabatic evaporation of water from the thermometer and the cooling effect is indicated by the wet bulb temperature lower or equal to the dry bulb temperature of the air. The rate of evaporation from the wet bandage on the bulb and the temperature difference between the dry bulb and wet bulb depend on the humidity of the air. The evaporation is reduced when the air contains more water vapor (Navarro and Noyes, 2001). The dew point temperature is that at which water vapor starts to condense out of the air or the temperature at which air becomes completely saturated. If the dew point temperature is close to the air temperature, the relative humidity is high and if it is well below the air temperature, the relative humidity is low (Brooker et al., 1992).

Humidity is the quantity of water vapor present in air. Relative humidity is the ratio of the mole fraction of water vapor to the mole fraction of saturated moist air at the same temperature and pressure. It is dimensionless and is usually expressed as a percentage. Humidity ratio, moisture content or humidity of air refer to the same quantity. This property differs from relative humidity in that it is the amount of water vapor by weight in the air. Generally it is defined as the mass of water contained in one kilogram of dry air (Wilhelm, 1976).

Enthalpy is the measure of the total energy in the air or the energy content per unit air weight. That is, enthalpy is the sum of the internal energy of the moist air in question, including the heat of the air and water vapor within. This property is read from where the appropriate wet-bulb line crosses the diagonal scale above the saturation curve. Air with same amount of energy may either be

dry hot air (high sensible heat) or cool moist air (high latent heat) (Brooker et al., 1992).

Specific volume is the volume per unit mass of the air sample. In other words, this property represents the space occupied by a unit weight of dry air and is the reciprocal of the density (Navarro and Noyes, 2001).

Basic psychrometric processes are heating, cooling, adiabatic humidification and air mixing, which can be combined according to different applications or equipment (Leal et al., 2000). Heating of the air occurs when energy is absorbed from a heat source and cooling occurs when the air loses its heat energy. Neither heating nor cooling change the humidity ratio and the partial pressure. However, if cooling occurs beyond the dew point, the air becomes saturated. As the air continues to cool, the moisture vapour within the air will lose energy as well, some of which will condense back into moisture droplets and release its latent heat of vaporization (Brooker et al., 1992). The term adiabatic simply means without energy loss or gain. Dehumidification occurs when the air comes into contact with a substance that absorb moisture directly from the air. In this process, the latent heat of vaporization is released back into the air, raising its temperature and reducing the humidity ratio. The humidification is the opposite process. In both humidification and dehumidification the net overall enthalpy remains the same (Navarro and Noyes, 2001).

When two air samples of different states are mixed, the resulting air lies in between the straight line connecting the two initial conditions. That is, the resulting condition will vary in proportion to the relative masses of the two air streams (Brooker et al., 1992).

This work aims to relate the accuracy of the analytical methods used to estimate the psychrometric properties and processes to the versatility of the psychrometric charts. For this, a software, called GRAPSI_DRAW, was developed to perform the calculations and to show the results in a graphical way.

2. METHODOLOGY

The software GRAPSI_DRAW was written in Delphi 6.0 and was divided in three modules. In the first one the psychrometric chart scales can be changed and the properties at any point in the chart can be viewed moving the mouse over it. In the second module the properties of an specific state point can be calculated by means of the supply of two known properties. In this module the user has the option of viewing lines indicating how each psychrometric property is graphically obtained. In the third module, the basic psychrometric processes can be graphically simulated. These processes can be simulated sequentially, resulting in a more complex event, or they can be simulated individually, indicating independent events. In all modules, the resulting sets are also showed in a written report. As much the chart as the

report can be saved for later analysis. Fig. 1 shows the basic algorithm of GRAPSI_DRAW.

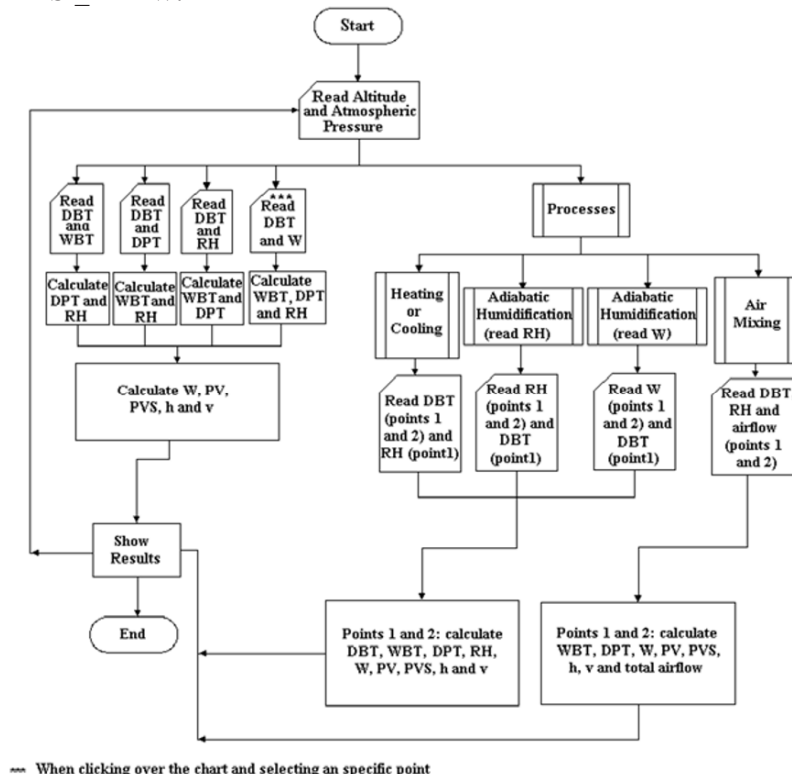


Fig. 1: Basic algorithm of GRAPSI_DRAW.

The equations used by the software are based on the information available in the American Society of Heating Refrigerating and Air-Conditioning Engineers Handbook of Fundamentals (Ashrae, 1972). Some equations were modified to produce results in SI units and others were replaced with more suitable because of better accuracy or ease of application under conditions such as wide range values (Zolnier, 1994; Navarro and Noyes, 2001; Wilhelm, 1976; Johannsen, 1981).

The saturation pressure must be accurate since it is used in calculating other properties. GRAPSI_DRAW uses equation 1 to determine this property due they be valid on a wide range of temperatures. Equation 1 is valid for temperatures from 0°C to 374°C (Johannsen, 1981).

$$PVS = \left(22087.83 \exp \left(\frac{0.01}{T} (100.98 - T) \sum_{i=1}^8 F_i (0.65 - 0.01 (T - 273.16))^{i-1} \right) + 0.00141 \exp(0.0386(T - 273.16)) \right) / 1000 \quad (1)$$

Where: PVS is the saturation pressure (kPa), T is the temperature (K) and the values of F vary as:

$$F_1 = -741.9242 \quad F_3 = -11.552860 \quad F_5 = 0.1094098 \quad F_7 = 0.2520658$$

$$F_2 = -29.210 \quad F_4 = -0.8685635 \quad F_6 = 0.4399930 \quad F_8 = 0.05218684$$

By using the perfect gas relationships, equations 2 and 3 are used for calculating partial pressure and specific volume, respectively (Navarro and Noyes, 2001; Wilhelm, 1976; Brooker et al., 1982).

$$PV = \frac{P_{\text{atm}} W}{0.622 + W} \quad (2)$$

$$v = \frac{0.28705 T}{P_{\text{atm}}} (1 + 1.6078 W) \quad (3)$$

Where: W is the humidity ratio (g g^{-1}), PV is the partial pressure (kPa), v is the specific volume ($\text{m}^3 \text{kg}^{-1}$) and Patm is the atmospheric pressure (kPa).

Equation 4, used to estimate the humidity ratio, is based on an energy balance for an adiabatic saturation process. This considers that the enthalpy of the incoming air plus the enthalpy of the water added must equal the enthalpy of the saturated air at its thermodynamic wet bulb temperature (Wilhelm, 1976).

$$W = \frac{(2501 - 2.41 \text{ WBT}) W_s - 1.006 (\text{DBT} - \text{WBT})}{2501 + 1.775 \text{ DBT} - 4.186 \text{ TWB}} \quad (4)$$

Where: WBT is the wet bulb temperature ($^{\circ}\text{C}$), DBT is the dry bulb temperature ($^{\circ}\text{C}$) and W_s is the humidity ratio at saturation (g g^{-1}).

To calculate the humidity ratio when the wet bulb temperature isn't known and at saturation equation 3 can be used.

Relative humidity, expressed in %, is defined as 100 times the ratio of the partial pressure divided by the saturated pressure at the same temperature (Johannsen, 1981).

Equation 5 is used to estimate the enthalpy. This equation considers that the enthalpy of the moist air is equal to the sum of the enthalpies of its components. So, the enthalpy of dry air was approximated closely as the product of specific heat and temperature, taking the value of specific heat equal to $1.006 \text{ J g}^{-1} \text{ K}^{-1}$ (Wilhelm, 1976).

$$h = 1.006 T + W [2501 + 1.775 T] \quad (5)$$

Where: h is the enthalpy (kJ kg^{-1}).

Since the temperature of saturated vapor is dependent only on the absolute pressure, the dew point temperature is calculated by using equation 6 (Zolnier, 1994).

$$\text{DPT} = \frac{186.4905 - 237.3 \log_{10}(10 \text{ PV})}{\log_{10}(10 \text{ PV}) - 8.2859} \quad (6)$$

Where: DPT is the dew point temperature ($^{\circ}\text{C}$).

The wet bulb temperature is derived using an iterative procedure. The software considers that this property lies somewhere between the dry bulb temperature and the dew point temperature. So, keeping enthalpy constant, the wet bulb temperature, starting from the dry bulb one, is decremented by a small delta and its correspondent relative humidity is calculated, until a value between 99.99 and 100% is found. The initial delta is 0.1 °C but, if a relative humidity greater than 100% is verified, delta is divided by two and the temperature is incremented by it.

When simulating air mixing input data are dry bulb temperatures, relative humidities and airflow of two samples of air. Starting from this, the psychrometric properties of the two initial points are calculated and the final condition is obtained from mass and energy balances. Equations 7, 8 and 9 are used to estimate the dry bulb temperature, the humidity ratio and the airflow of the mixture, respectively. Other properties are calculate by making use of basic equations presented previously in this paper (Lopes et al., 2000).

$$DBT_M = \frac{u_1 DBT_1 + u_2 DBT_2}{u_1 + u_2} \quad (7)$$

$$W_M = \frac{u_1 W_1 + u_2 W_2}{u_1 + u_2} \quad (8)$$

$$h_M = \frac{u_1 h_1 + u_2 h_2}{u_1 + u_2} \quad (9)$$

Where: u is the airflow ($m^3 h^{-1}$), index M denotes the mixture properties, index 1 denotes the first sample properties and index 2 denotes the second sample properties.

The required input data to simulate heating and cooling processes are the dry bulb temperatures of the two state points and the relative humidity of the first one. With these input data, all psychrometric properties of the first point can be estimated by using the known equations. Since during these processes the humidity ratio and partial pressure are unchanged, the properties of the second point also can be calculated by using the same equations. Condensation is verified when the dry bulb temperature of point 2 is smaller than the dew point temperature of point 1. In this case, relative humidity of point 2 is assumed as 100% and the other properties, including the humidity ratio and the partial pressure, are calculated considering this new situation (Zolnier, 1994).

The adiabatic humidification can be simulated by knowing the relative humidities or the humidity ratios of two state points, besides the dry bulb temperature of the first one. As two properties of point 1 are known, the other psychrometric properties of it can be easily calculated. Thus, keeping the enthalpy and, consequently, the wet bulb temperature constant, the

properties of the second point can be also calculated by using the known equations. If humidity of second point is smaller than that of the first one, the dehumidification process is simulated.

3. RESULTS AND DISCUSSION

GRAPSI_DRAW was tested over a wide range of conditions and the results obtained from each module were compared to tabulated values. All results agreed well with the theory. The most notable differences were with dew point temperature and enthalpy which presented maximum errors of 1.5% and 1.0% at higher temperatures.

Figures 2 to 4 present examples of use of GRAPSI_DRAW for the three available modules.

As illustrated in Figure 2, using the module “Chart”, the graph settings can be selected and psychrometric properties of different points can be estimated. The chart can be viewed by selecting the “Plot graphic” option. When passing the mouse over any area of the chart, main psychrometric properties are showed in the upper part of screen. All properties can be viewed in a report through a single click on some state point. Options “Save”, “About” and “Exit” can be used to save the results, view information about the software and close the software, respectively.

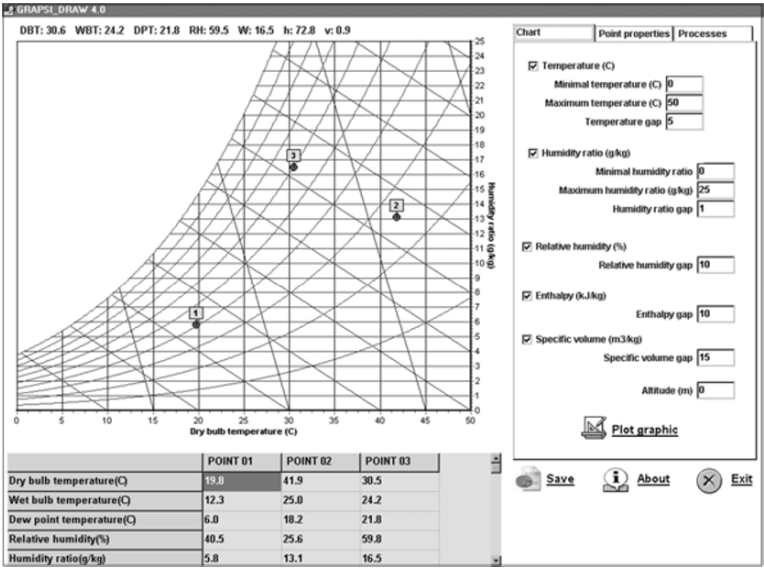


Fig.2: Module “Chart” of GRAPSI_CHART.

Figure 3 presents the software interface when the module “Point properties” is selected. User should inform the dry bulb temperature of the point and some one of the three other properties: wet bulb temperature, dew point temperature or relative humidity. The properties of the input point can be calculated by clicking on the “Plot graphic” option. An interesting feature of this module, which is useful for didactic purposes, is the possibility of viewing lines that illustrate how to read the chart. Also in this module graph and report can be saved.

Viewing Figure 4 it’s possible verify that various psychrometric processes can be simulated sequentially by using the module “Processes” of GRAPSI_DRAW, including cooling with condensation. After selecting the process and inform required input data, the user should only click on the “Plot graphic” option to view the results. When selecting “Clear” the chart and the report are deleted, allowing new simulations in combination or individually. As well as other modules, graphical and written results can be saved.

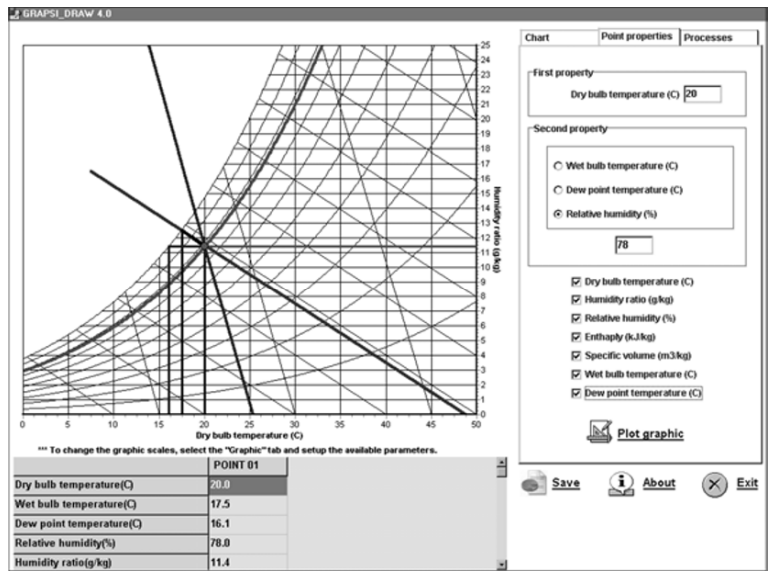


Fig 3: Module “Point Properties” of GRAPSI_DRAW.

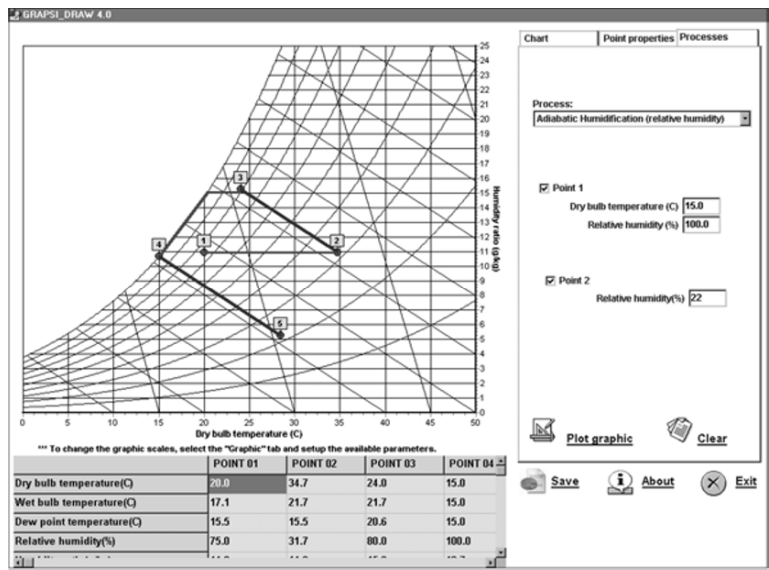


Fig 4: Module “Processes” of GRAPSI_CHART.

4. CONCLUSION

GRAPSI_DRAW is an efficient tool for all professionals that work with psychrometry. This software is capable of efficiently calculate the psychrometric properties of air and simulate psychrometric processes. Its friendly interface is suitable as for didactic purposes as for speeding up analysis involving psychrometry.

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FORECASTING CROP WATER REQUIREMENT BY ET-HS MODEL FOR ARID AND SEMI ARID REGION OF IRAN

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Abstract: Estimating actual crop water requirement and irrigation schedule are essential for designing of the irrigation systems, storage construction and water conveyance structures. Many models have developed for estimating crop water requirement. Although most of these methods need different climatic parameters, providing and forecasting all of these parameters always are not available. Most of the time, some of these forecasted parameters are incorrect, through of these the maximum and minimum temperature are more accurate. In addition, temperature is the most affective factor on evapotranspiration in arid and semi-arid region. In this paper, ET-HS has been presented which after calibration by regional factors, could be predicted the time of irrigation. This model only needs daily maximum and minimum temperature for this prediction.

Keywords: model, forecasting, crop water requirement, irrigation schedule, evapotranspiration, arid and semi-arid region

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1. INTRODUCTION

By the increase of the world population especially in the developing countries has caused serious lacking of food. In addition, the situation which causes climate changes and repeated droughts in recent years have resulted that fresh water became scarce. The shortage of surface fresh water has caused anomalous usage of ground water resource (Arvandi and Kamyab-Moghadas, 2001). In these conditions, calculating evapotranspiration, accurate plants water requirement (CWR) and prediction of irrigation schedule has a great deal of importance for saving water resource.

A large number of scientists have developed numerous equations to compute potential evapotranspiration (ET_0) during the last 50 years (Allen et al., 1998). These equations range from the most complex energy balance equations requiring detailed climatological data (Allen et al., 1998) to simpler equations requiring limited data (Samani 2000). Some of the studies showed that the radiation and temperature methods could estimate ET_0 better than other methods, especially in arid and semi-arid regions (Najafi and Tabatabaei, 2007). Among the numerous methods, the Hargreaves-Samani is ones that having a global validity and estimating ET_0 based on temperature. Najafi et al. (1999) compared several methods for estimating ET_0 with actual evapotranspiration data for reference grass in Isfahan, IRAN. They concluded that the Hargreaves-Samani could be satisfactorily used to estimate potential evapotranspiration in Isfahan, IRAN. Najafi and Tabatabaei (2005) improved the Hargreaves-Samani for arid and semi-arid region. ET-HS is a model which used improved Hargreaves-Samani equation and was developed by Najafi (2002). Najafi and Mousavi (2002) compared CropWat and ET-HS computer models based on grass lysimeter data in 10 different arid and semi-arid regions of Iran and concluded that estimation of ET_0 using ET-HS model was more precise than CropWat.

The objective of the present paper is the description of ET-HS method which is suitable model for the evaluation of daily water consumption, actual crop evapotranspiration (ET_c) and irrigation schedule of crops during the crop growth period in arid and semi-arid region.

2. METHOD

2.1 Potential Evapotranspiration

In this model, four equations have presented for estimating the ET_0 . The equations have selected based on regional wind speed (W) condition and

after that the model checks the ET_0 value. If the ET_0 is more than 6mm/day, the model recalculates the ET_0 by another equation. The Figure 1 shows the process of ET_0 calculating in ET-HS model.

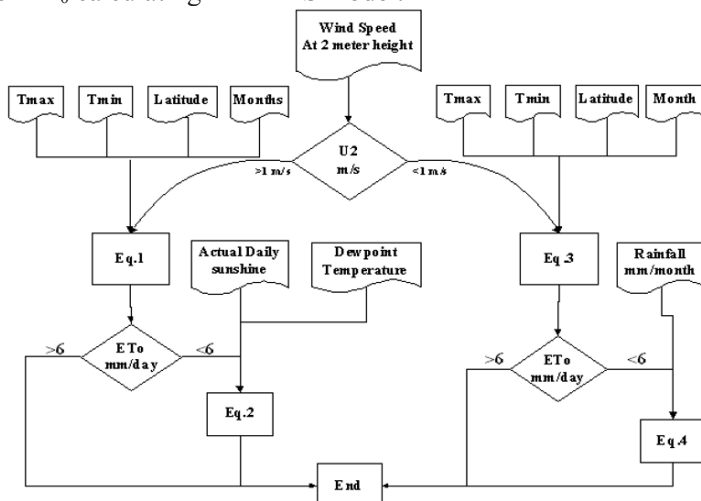


Fig.1: ET-HS model for estimating Potential Evapotranspiration

In case that $W < 1$ m/s, Najafi (2002) improved Hargreaves-Samani for arid and semi-arid region of IRAN as eq. 1:

$$ET_0 = 0.002 \times R_A \times TD^{0.5} \times (T_a + 17.8) + 0.4 \quad (1)$$

Where, R_A ; is Extraterrestrial radiation [mm/d], $TD = T_{\max} - T_{\min}$, $T_a = (T_{\max} + T_{\min})/2$ and $T_{\max}$ and $T_{\min}$ are daily maximum and minimum Temperature [$^{\circ}\text{C}$]. If after in above equation, ET_0 has been more than 6 mm/d, the model recalculates ET_0 by eq. 2:

$$ET_0 = 0.0077 \times K_{RS} \times R_A \times [T_{\max} - T_d]^{0.5} \times (T_a + 17.8) \quad (2)$$

Where, T_d is dew point temperature. In each location, it could be found a linear regression between minimum temperature and dew point temperature. In addition, K_{RS} is Hargreaves-Samani Coefficient which could be calculated in each an area by location long term values of ratio actual daily sunshine and measurement daylight hours. This linear regression, it must be inputted as a calibration factor before starting model.

In case that the $W > 1$ m/s, the model presented eq. 3:

$$ET_0 = 0.0025 \times R_A \times TD^{0.5} \times (T_a + 17.8) - 0.42 \quad (3)$$

If after in above equation, ET_0 has been more than 6mm/d, the model recalculates ET_0 by eq. 4:

$$ET_0 = 0.001 \times R_A \times (T_a + 17) \times [(T_{\max} - T_d) - 0.0123 \times P]^{0.76} + 1.5 \quad (4)$$

Where, P; is precipitation [mm/day].

2.2 Actual crop evapotranspiration

ET-HS model calculates actual plant evapotranspiration with consideration irrigation water quality and soil moisture condition. In addition, the irrigation system and evaporation from soil surface are the others parameters which must be considered in ETc. For this way, the following equation has presented:

$$ET_{c(i,j)} = (K_{s(i,j)} \times K_{m(i,j)} \times K_{cb(i,j)} + E/q \times K_e(i,j)) \times ET_{0(i,j)} \quad (5)$$

Where, K_s ; is salinity stress coefficient [-], K_m ; soil water stress coefficient [-], K_{cb} ; basal crop coefficient [-], E/q ; evaporation losses [mm/mm](this parameter directly relates to irrigation system) , K_e ; soil evapotranspiration coefficient [-] and ET_0 ; reference evapotranspiration (mm/day). i ; number of the day after recent irrigation and j ; number of the day in growing season. Each of above mention factors are estimated daily based on regional input information which presented in Figure 3.

2.3 Readily available water

Based on this model, irrigations were achieved when total crop water requirement in i day after recent irrigation were equal or less than readily available water at day i in irrigation period

$\sum_0^i CWR(i,j) \geq RAW_j$. RAW equation is:

$$RAW_j = \frac{1000MAD_j(\theta_{FC} - \theta_{PWP})Z_j}{4WU_{cq}} \quad (6)$$

Where, MAD is maximum allowable depletion [percent], θ_{FC} ; volumetric soil water content at field capacity [$m^3 m^{-3}$], θ_{PWP} ; volumetric soil water content at wilting point [$m^3 m^{-3}$], Z ; crop root zone [m], WU_{cq} ; moisture extraction pattern for critical quarter of crop root zone [percent], i ; number of the day after recent irrigation and j ; number of the day in growing season.

2.4 Crop water requirement

Daily plant crop water requirement estimates as follows:

$$CWR_{(i,j)} = \frac{ET_{c(i,j)}}{1 - \max(LR_{EC}, LR_{SAR}, LR_{CI})} \quad (7)$$

Where, LR_{EC} , LR_{SAR} and LR_{CL} are leaching requirement for salinity, sodium absorption ratio and chloride , respectively . In the above equation the maximum leaching requirement selects for calculating CWR.

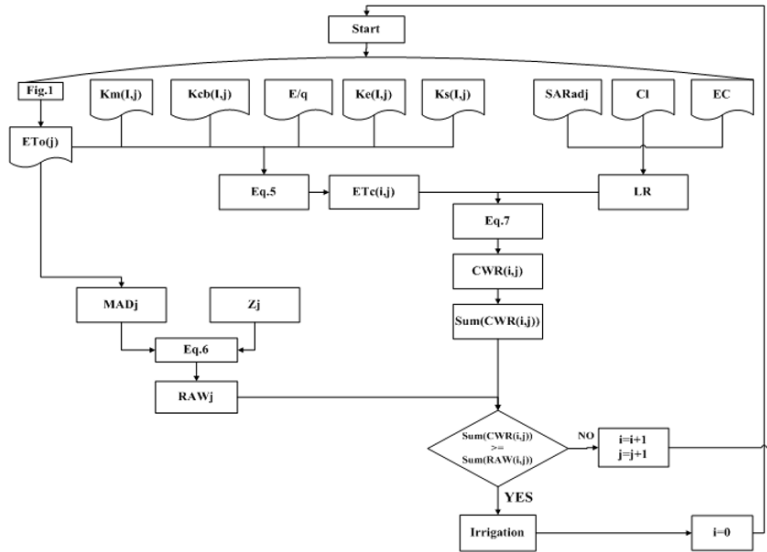


Fig.2: ET-HS model.

2.5 Regional input Data for calibration model

Before starting the application model in each area, It must be inputted some parameters for calibration the model. The parameters are classified into four groups. The first group is included basal crop coefficient (K_{cb}), maximum effective rooting depth, planting date and lengths of crop development stages (L). If these values for selected crop are not available on an area, these could be found in FAO No. 56 (Allen et al., 1998). Based on these initial information, the generalized crop coefficient curve and effective rooting depth curve through the four growth stages (Allen et al., 1998) are drawn and arrived into calculating process.

The second group of input values is irrigation water quality indexes as description on Fig. 3. These parameters are arrived to actual crop evapotranspiration (eq. 5) and crop water requirement (eq. 7) estimating process. The thrid group is soil physical parameters which is essential for computing RAW (eq. 6). The fourth group is climatic and geographic data which intoduced as “Regional Condition” in Fig. 3. Climatic parameters can be collected from values of synoptic stations database through several years ago.

2.6 Daily Input Data

After inputting the different regional information into the model, for calibration, the model is ready to start. For forecasting irrigation schedule and amount of irrigation water, the model only needs two parameters. These two parameters are daily maximum and minimum temperature (Fig. 3). Temperature parameter is the most accurate climatic factor which is forecasted by meteorology organizations; therefore the model could be very successful to predict irrigation event and CWR through future days. This is very important for saving water, especially in arid and semi-arid region, where the fresh water is scarce.

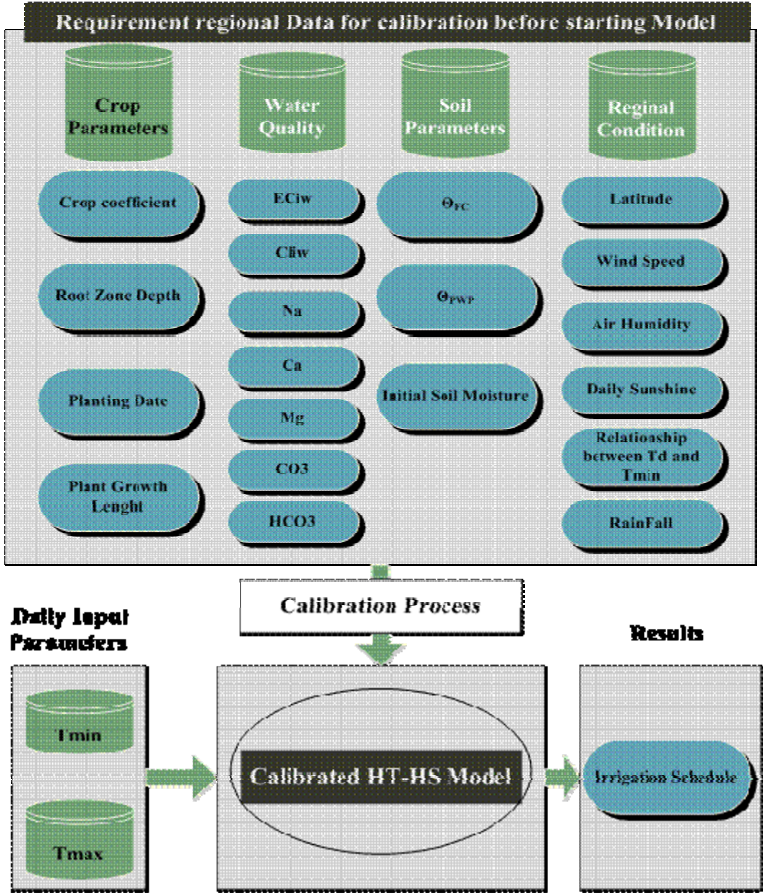


Fig.3: ET-HS process for estimating irrigation schedule.

3. CONCLUSION

Many methods were presented for irrigation water management through several recent years. But most of these have not suitable response to predict amount of irrigation water in arid and semi-arid region. These methods require wide different weather parameters while accurate measurement all of these factors is very difficult. In addition, some of studies indicated that the temperature provide satisfactory estimate of ET_0 for Middle East arid and semi-arid region. Furthermore, among of climatological factors, temperature has a highest accurate in forecasting sites.

ET-HS is estimating amount of irrigation water and irrigation period with minimum climatological variable. Weather parameters, crop characteristics, management and environmental aspects are factors affecting on crop evapotranspiration and irrigation water requirement. In ET-HS model, these parameters as constant factors are arrived to the model and after calibration model, with using daily maximum and minimum temperature as variable factors, it's predicted irrigation event and water requirement for selected crop.

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SIMULATION AND PREDICTION OF CD CUMULATION IN SOIL IRRIGATED BY RECLAIMED WATER BASED ON MATLAB

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Abstract: Based on the hypothesis that reclaimed water for irrigating is the cardinal source of heavy metals pollution in soil, and the heavy metals leave from soil mainly by plant harvest, the article constructs a differential equation and simulates the cumulation of Cd in wheat soil of southeast suburb in Beijing based on simulink of matlab. With the data relative Cd mass proportion in soil as predictor parameter in stems and leaves as response ones, the fitting curves are produced respectively. The curves show that the amount of Cd leave from soil is very small compared with the amount entering into soil via irrigation water. But in the condition of lower concentration in soil, the proportion of Cd left from soil is bigger relatively. The prediction shows that the content of Cd will exceed the national standard of China after 40 years in the condition of the content of Cd in reclaimed water with $10\text{mg} \cdot \text{m}^{-3}$ and concentration in soil with $0.1333\text{mg} \cdot \text{kg}^{-1}$, but it should be 100 years if the concentration of Cd in reclaimed water for irrigation reduced to $5\text{mg} \cdot \text{m}^{-3}$.

Keywords: reclaimed water, soil, Cd, simulation and prediction

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1. INTRODUCTION

In China, the development of industry and economy is on the way of transition, and agriculture irrigation still consumes the largest water resource, which proportion should be over 65%. The water resource is not abundant in China, the average of a person's possession of water resource is about 2300m^3 , which equals 1/4 of the world average. China is the largest agriculture country in the world, in 1998 the area of irrigation land is $0.53 \times 10^8 \text{hm}^2$, and in 2006, $0.56 \times 10^8 \text{hm}^2$. So the conflict in using water resource shows very consuming in China. The lack of agriculture water resource could reach $300 \times 10^8 \text{m}^3$, meanwhile the total lack in China is $360 \times 10^8 \text{m}^3$ (M.Ma et al.,2006).

The use of poor quality irrigation water generally can be divided into three stages, before 1957, the spontaneous period, and since the 1940s, Beijing began to use the surrounding industrial waste water for irrigation, until the late 1950s, domestic awareness of environmental issues is not serious, consider to increase agricultural production from resource of water and fertilizer in town sewage, but also to resolve the issue of way out of industrial wastewater, should be vigorously promoted. Because at that time the sewage emission was little, to the 1963 national sewage irrigation area of $4.2 \times 10^4 \text{hm}^2$, the environmental impact of sewage irrigation was not obvious. It went into the second phase, 20 late 1960s to the mid-1970s, the rapid development period, in 1957 the Ministry of Agriculture and Ministry of Medical setoff to research the project of sewage irrigation. At this stage, the development of sewage irrigation was rapid, China's sewage irrigated area reached $9.3 \times 10^4 \text{hm}^2$ in 1972, and environmental issues during that period gradually aroused community attention, but due to the tense situation of the agricultural water resource and increasing sewage emissions, many farmland near cities increased use of sewage irrigation, in 1976, national sewage irrigation area has increased to $18.0 \times 10^4 \text{hm}^2$. 1972 date for the third stage, is actively and carefully stage of development, in 1972 in Shijiazhuang national conference of sewage irrigation meeting to draw up a "positive cautious" approach to development, and formulated the interim sewage irrigation water quality standards. China in the early 1980s sewage irrigation area was about $133.3 \times 10^4 \text{hm}^2$, of which, Tianjin has reached more than $15.3 \times 10^4 \text{hm}^2$, which was the largest one, Beijing reached $8.9 \times 10^4 \text{hm}^2$, in addition, Xi'an, Shijiazhuang, Taiyuan, Ji'nan and Shenyang is also famous sewage irrigation district (X.H. Hu, 1999). In 1991, sewage irrigation area developed to $306.7 \times 10^4 \text{hm}^2$, and 1980's average annual growth rate reached 11.5 percent. The result of irrigation using reclaimed water is that the soil and environment was degraded and the yield was decreased in some places.

Cd is not indispensable to human. When the environment is polluted, Cd may cumulate in kidney of human, make pathological changes of kidney and liver, and farther, the bones, alimentary canal and vascular pathological changes. Last century the FuShan Event of Japan is due to the Cd pollution of rice and drinking water in FuShan area in Japan. Reclaimed water is a kind of resource refreshed from city sewage, which measures up to certain standards and can apply in some situation. The second treatment water from wastewater treatment factory may be often applied to irrigate for the economic reasons (M.Ma et al., 2006), but its some indexes may not match the standard of irrigation, for example the Gaobeidian Wastewater Treatment Plant in China--the biggest wastewater treatment factory in China, which proportion of Cd in second treatment water is about $10\text{mg}\cdot\text{m}^{-3}$ in continuously three years. In China the area of arable land polluted by heavy metal is $2\times 10^7\text{hm}^2$, which have 1/6 of the arable area(Q.X. Zhou. 2005)

2. MATERIALS AND METHODS

The absorption coefficient of plant to Cd is higher than Cu, As and Pb, so the transference ability of Cd is stronger in soil-plant system. Cd may cumulate in plant and endanger the health of human in the condition of long-term irrigation using reclaimed water. Research in Xi'an and Beijing in China shows that the irrigation of shot time has not caused heavy metal exceeding the national standards (T.H. Sun.,2005), but research to long-term cumulating is scarce. This research is about simulation and prediction to the cumulating rule of Cd in soil by long-term irrigation using reclaimed water.

A great deal of experiments show that heavy metal stay the surface layer and scarcely transfer down to underground in dry farming soil (T.H. Sun.,2005). Heavy metal in irrigated farming soil can always stay in the cultivated layer for cultivating. Based on the data from references and our experiments (Table 1) and according to data character we can make fitting curves modeled as $y=a \cdot x^b$. The fitting curves produced with the data of relative Cd mass proportion in soil as predictor parameter and in stems and leaves as response ones, which result can be described as Fig 1. Adjusted R^2 shows the fitting is satisfying.

The heavy metal pollution derives mainly from irrigation water but not dry or wet sedimentation in the area where inferior water is used, namely the main source of heavy metal in soil is irrigation water (N.M. Zhang, 2002, M. Del,2002). Here we presume the primary reason of digressions of Cd in soil is the absorption of plant for Cd from soil to the environment (T.H. Sun , 2005), and presume Cd in soil can not cause the plant product decline

evidently or it has been remedied by some ways, for example irrigation water or fertilization measure, then the prediction can be processed by means of designing some formula.

Table 1. Content of Cd in soil & plant Unit: mg • kg⁻¹

Sn	Item	Code	Content of Cd				
1	soil-1	x1	0.22	0.48	1.84	9.55	112.50
	wheat stem & leaf	y11	0.93	2.04	6.45	8.00	49.00
	wheat seed	y12	0.08	0.12	0.89	1.30	3.22
2	soil-2	x2	0.24	3.12	4.98	29.50	296.50
	rice stem & leaf	y21	0.15	4.56	11.20	50.00	198.00
	rice seed	y22	0.064	0.54	0.78	1.32	1.57

Partially based on reference [4]

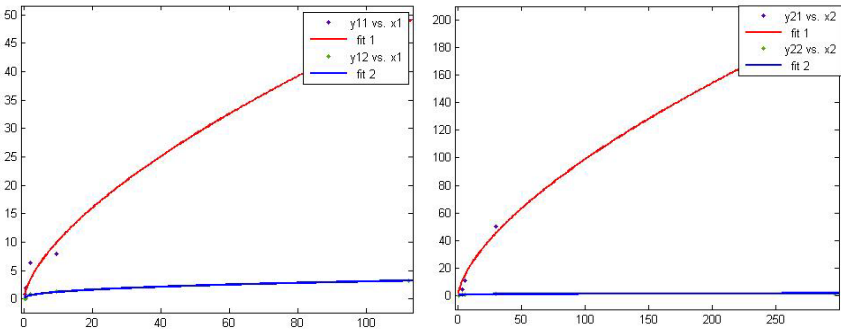


Fig.1. Curve-fitting illustration (wheat & rice)

3. RESULTS

We can do some more appointment according to the cultivation condition in North China that the quantity of irrigation water is 6000m³ • hm⁻²; 75% of biomass may leave the soil and seed will be harvested entirely. For wheat, the yield may be about 6.75t • hm⁻², stem and leaf in biomass is 4.5t • hm⁻², and the arable soil may be about 2250t • hm⁻². Then, (1) the mass of Cd leaving the soil:

(0.75 • 4.5 • y11 + 6.75 • y12) • 1000
= (3.375 • y11 + 6.75 • y12) • 1000/mg • hm⁻²

and (2) the mass entering into the soil:

6000c/mg • hm⁻².

here, y11-Cd mass in stems and leaves of wheat, mg • kg⁻¹; y12-Cd mass in seeds of wheat, mg • kg⁻¹; c- Cd mass in irrigation water , mg • kg⁻¹.From this, we can produce a equation, the residue ratio of Cd in soil:

$$K=\frac{x1\cdot 2.25\times 10^6-(6000\cdot c-(3.375\cdot y11+6.75\cdot y12)\cdot 1000)}{x1\cdot 2.25\times 10^6}$$

here, K--the residue ratio of Cd in soil of year, %; x1--Cd mass in soil ,
mg • kg⁻¹.

Substituting fitting results in table2 y11=2.318 • x1^{0.6435} ,
y12=0.5044 • x1^{0.3944} for the parameter of K equation, we can have:

$$K=\frac{x1\cdot 2.25\times 10^6-(6000\cdot c-(7.823\cdot x1^{0.6453}+3.405\cdot x1^{0.3944})\cdot 1000)}{x1\cdot 2.25\times 10^6}\tag{1}$$

On the other hand, treating x1 as a continuous variable we can have:

$$\frac{dx1}{dt}=\frac{6000\cdot c-(7823\cdot x1^{0.6453}+3405\cdot x1^{0.3944})}{2.25\cdot 10^6}\tag{2}$$

hear, t--time, a. This is an ordinary differential equation with the initial
value $x1|_{t=0}=B$ (background value). The background value of ratio of Cd
mass in arable soil in the southeast suburb of Beijing City of China is:
 $B=0.1333\text{mg}\cdot\text{kg}^{-1}$, which is found by our scene inspecting. The other
results on the irrigation water from Gaobeidian Wastewater Treatment Plant
is that the content of Cd in the second treatment water is: $c=10\text{mg}\cdot\text{m}^{-3}$.
Continuous monitor for 3a shows that the content is stable. Then the
simulation for x1 can be made and the result is indicated by table3 and Fig.2
based on Simulink of Matlab. The model of Simulink showed by Fig.3.

Table 2. Result of curve-fitting

Expressions	a (with 95% confidence bounds)	b (with 95% confidence bounds)	Adjusted R ²
y11=a • x1 ^b	2.318 (-0.1408, 4.776)	0.6453 (0.4166, 0.8741)	0.9892
y12=a • x1 ^b	0.5044 (0.1255, 0.8832)	0.3944 (0.2229, 0.5659)	0.9649
y21=a • x2 ^b	5.129 (1.519, 8.739)	0.6423 (0.5162, 0.7684)	0.9964
y22=a • x2 ^b	0.4841 (0.03934, 0.9288)	0.2203 (0.02374, 0.4169)	0.813

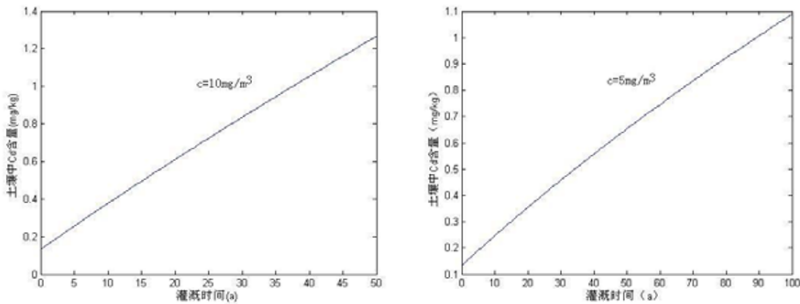


Fig.2. Curve of Cd's concentration in soil

Table 3 showed that the concentration of Cd in soil will exceed the third level standard of Environmental Quality Standard for Soils (GB15618-1995), namely $1.0\text{mg} \cdot \text{kg}^{-1}$ after 40 years. From Fig. 2 we can see that the concentration rise linearly, which indicates that the proportion of Cd leaving the soil via plant harvest versus entering the soil is very small. Considering the improving on wastewater treatment and descending the concentration of Cd in irrigation water to $c=5\text{mg} \cdot \text{m}^{-3}$, then the result will show that the time is about 100 years after the concentration of Cd reach $1.0\text{mg} \cdot \text{kg}^{-1}$, which validate that the concentration for $5\text{mg} \cdot \text{m}^{-3}$ as the standard is rational.

Table3 Forecast of Cd's content in soil

Time of irrigation /a	1	10	20	30	40	50	100
Concentration of Cd $c=10\text{mg} \cdot \text{m}^{-3}$	0.1333	0.3531	0.5872	0.8131	1.0321	1.2450	---
in soil $/\text{mg} \cdot \text{kg}^{-1}$ $c=5\text{mg} \cdot \text{m}^{-3}$	0.1333	0.2469	0.3548	0.4581	0.5574	0.6532	1.0068

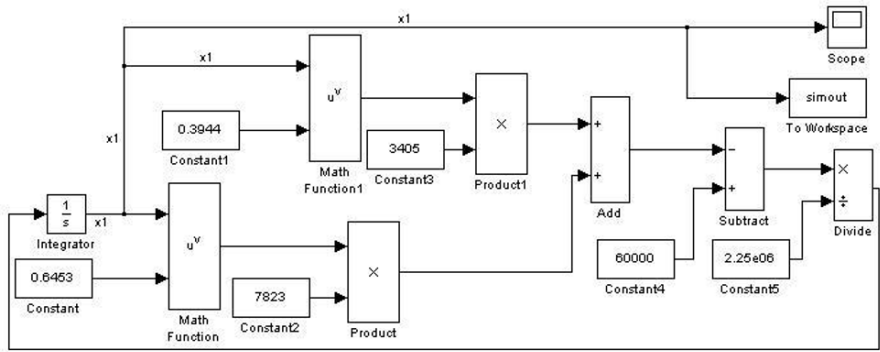


Fig.3. Model of Simulink

The heavy metal in soil comes mainly from irrigation water in dry region in China, which has been focused on by people because heavy metal pollutions have the character of concealment, long-term delitescence, strong toxicity and difficulty to treatment. The research above showed that the Cd proportion leaving the soil with plant harvest is very small compared with entering into with irrigation. The result of simulation showed that the concentration of Cd in soil will exceed the national standard of China, $1.0\text{mg} \cdot \text{kg}^{-1}$, after 40 years if using the second treated water from Gaobeidian Wastewater Treatment Factory, and if the concentration descend below $5\text{mg} \cdot \text{m}^{-3}$, the time can be about 100 years.

4. DISCUSSIONS

Reclaimed water derived from the domestic sewage of city whose contents of organic compound, inorganic compound and suspended particles are very complex, but the concentration is light. So it may not cause serious environmental problems to irrigate with reclaimed water, but there are latent menace to soil environment, so the long-term irrigation using reclaimed water should be attached more importance. This research indicates that the heavy metal pollutions would be inevitable if the wastewater treatment technique not be improved.

The research doesn't take the pH's effects to fittings into account, although the variety of pH is an important factor for the activity and absorptivity to plant, which can be consider at more research. More research can be processed based on this research, such as the choice between the alternate or mix irrigation. Considering the cost of different irrigation technique, it can be researched the feasibility of irrigation using reclaimed water. We can predicate plant restoring time of heavy metal pollution of soil by super-accumulation plant.

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NUMERICAL SIMULATION OF AIR-WATER BUBBLY FLOW IN AXIAL FLOW PUMP IMPELLER

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Abstract: In this paper, the lift-law method was applied to design the axial flow pump. Based on Reynolds time-averaged N-S equations and standard $k-\varepsilon$ turbulent model, three-dimensional air-water bubbly flow in an axial flow pump impeller was simulated. Under the condition of bubble void fraction of 5%, pressure and void fraction distributions were respectively obtained, movement of bubbles in the impeller channel was analyzed. The numerical results demonstrate that air bubbles accumulate at the blade back near the impeller inlet because the lowest pressure on blade back happens here.

Keywords: axial flow pump, impeller, numerical simulation, air-water bubbly flow

1. INTRODUCTION

Axial flow pump possesses the characteristics of large flow rate, low head and simple structure, and has been widely used in agricultural and industrial engineering fields as an important transporting device. During the last decade, there has been a growing interest in pumping two-phase mixtures. Usually, the appearance of gas in the liquid leads to a strong decrease in efficiency. With respect to the development of turbo-machines with improved performance in the multiphase flow region, it is important to

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acknowledge information of each phase's parameter distributions inside the pump (H.-M.Prasser et al ,2003). Relevant studies of internal flow with computational fluid dynamics (CFD) are mainly focused on pure water flow conditions. As for multiphase flows in axial flow pump impeller, especially the air-water flow involving bubble-flow interaction, few researches are reported. So the present work focuses on visualizing the gas fraction distribution inside the rotating impeller of an axial flow pump delivering two-phase fluid.

Under the condition of bubble void fraction of 5%, this paper adopts commercial CFD software FLUENT to simulate the air-water bubbly flow in an axial flow pump impeller.

2. NUMERICAL SIMULATION

2.1 Computation model

The designed axial flow impeller has 4 blades, outlet diameter of 200mm and hub diameter of 104mm. The pump operates at flow rate of 360 m³/h and rotation speed is of 1450 r/min(See Fig.1).

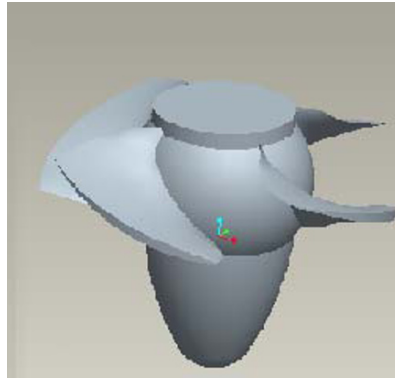


Fig.1.Three-dimensional model

2.2 Governing equations

As the pump impeller rotates at uniform angular speed, a necessarily established rotating Cartesian coordinate system rotates synchronously with impeller and coincides with impeller's axis. The convection terms of control equations are discretized with a second order upwind scheme, while the source term and diffusion term are handled with second order central differential scheme(YU Zhi-Yi et al,2007) .Based on Reynolds time-averaged N-S

equations, with hypothesis of Bossinesq eddy viscosity coefficient (Falcimaigne J et al, 2005), the basic equations to be solved contain the continuity equation

$$\frac{\partial}{\partial t}(\alpha_l \rho_l) + \frac{\partial}{\partial x_i}(\alpha_l \rho_l u_{li}) = 0 \quad (1)$$

$$\frac{\partial}{\partial t}(\alpha_g \rho_g) + \frac{\partial}{\partial x_i}(\alpha_g \rho_g u_{gi}) = 0 \quad (2)$$

and the momentum equations

$$\frac{\partial}{\partial t}(\alpha_g \rho_g u_{gi}) + \frac{\partial}{\partial x_j}(\alpha_g \rho_g u_{gi} u_{gj}) = -\alpha_g \frac{\partial p}{\partial x_i} + \alpha_g \rho_g f_{gi} + M_{gi} \quad (3)$$

$$\begin{aligned} \frac{\partial}{\partial t}(\alpha_l \rho_l u_{li}) + \frac{\partial}{\partial x_j}(\alpha_l \rho_l u_{li} u_{lj}) = & -\alpha_l \frac{\partial p}{\partial x_i} \\ & + \frac{\partial}{\partial x_j} \left[\alpha_l \mu_t \left(\frac{\partial u_{li}}{\partial x_j} + \frac{\partial u_{lj}}{\partial x_i} \right) \right] + \alpha_l \rho_l f_{li} + M_{li} \end{aligned} \quad (4)$$

where subscript g and l represent gas phase and liquid phase respectively.

2.3 Turbulent models

With the $k - \varepsilon$ turbulent model, the equations has the form the k equation:

$$\begin{aligned} \rho \frac{\partial(\alpha_l \rho_l k)}{\partial t} + \frac{\partial(\alpha_l \rho_l u_{lj} k)}{\partial x_j} = & \frac{\partial}{\partial x_j} \left[\alpha_l \frac{\mu_t}{\sigma_k} \frac{\partial k}{\partial x_j} \right] \\ & + \alpha_l \mu_t \frac{\partial u_i}{\partial x_j} \left(\frac{\partial u_j}{\partial x_i} + \frac{\partial u_i}{\partial x_j} \right) - \alpha_l \rho_l \varepsilon \end{aligned} \quad (5)$$

the ε equation:

$$\begin{aligned} \frac{\partial(\alpha_l \rho_l \varepsilon)}{\partial t} + \frac{\partial \alpha_l \rho_l u_j \varepsilon}{\partial x_j} = \frac{\partial}{\partial x_j} \left[\alpha_l \frac{\mu_t}{\sigma_\varepsilon} \frac{\partial \varepsilon}{\partial x_j} \right] \\ + \alpha_l \mu_t \frac{c_1 \varepsilon}{k} \frac{\partial u_j}{\partial x_j} \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) - c_2 \alpha_l \rho_l \frac{\varepsilon^2}{k} \end{aligned} \quad (6)$$

Where σ_k and σ_ε are Prandtl numbers of k and ε respectively, of which $\sigma_k = 1.0$, $\sigma_\varepsilon = 1.3$. And other parameters are as follows: $C_\mu = 0.09$, $C_1 = 1.44$, $C_2 = 1.92$.

3. BOUNDARY CONDITIONS

According to the flow characteristics at the inlet of impeller, law of mass conservation and hypothesis of irrotationality, inlet axial velocity is determined. Tangential velocity and radial velocity are set to zero. Turbulent kinetic energy at the inlet is 1% of average kinetic energy of the bulk flow. And its dissipation rate is deduced from turbulent kinetic energy and characteristic length of inlet, that is

$$\varepsilon_{in} = \frac{c_\mu^{3/4} k_{in}^{3/2}}{k y_m} \quad (7)$$

Where y_m is distance between calculation point and the wall.

At the outflow boundary of the computational region, velocity, turbulent kinetic energy and its dissipation rate are defined with Neuman boundary condition.

$$\frac{\partial \phi}{\partial n} = 0 \quad (\phi = u, v, w, k, \varepsilon) \quad (8)$$

At solid walls, Neuman boundary condition is used in gas fraction, and the no-slip boundary condition is applied to air-water two-phase velocities ($u, v, w = 0$). Near the wall, the wall function method is employed, the distance between point P and the wall is denoted by y_p , so that velocity of point P u_p , turbulent kinetic energy k_p and its dissipation rate are determined by (Lauder B E et al, 1974).

$$\frac{u_p}{u_\tau} = \frac{1}{\kappa} \ln(E y_p^+) \quad (9)$$

$$k_p = \frac{u_\tau^2}{\sqrt{C_\mu}}$$

(10)

$$\varepsilon_p = \frac{u_\tau^3}{\kappa y_p}$$

(11)

Where $y_p^+ = \frac{\rho u_\tau y_p}{\mu} = \frac{\rho c_\mu^{1/4} k_p^{1/4} y_p}{\mu}$, skin friction coefficient $u_\tau = \sqrt{\tau_w / \rho}$. E and κ are constant and defined as 9.011 and 0.419 respectively .

4. RESULTS

4.1 Static pressure distributions

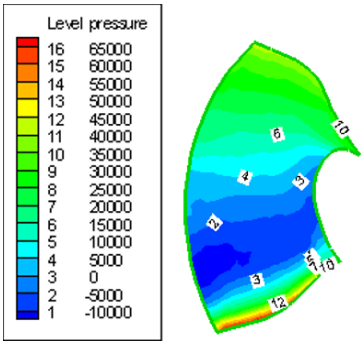


Fig.2.static pressure distribution on blade back of the impeller

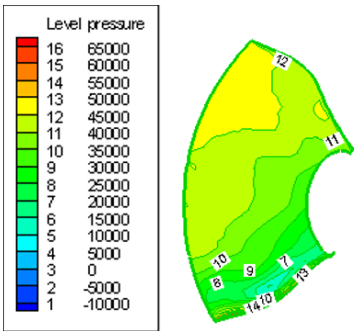


Fig.3. static pressure distribution on blade front of the impeller

As shown in Fig.2, pressure contours on blade back progress in radial direction and get intensive approaching the leading edge. It is found that an obvious low-pressure area exists at the blade tip near the impeller inlet.

Except the leading edge, pressure contours on blade front are sparse in Fig.3. Pressure variation mainly occurs in radial direction and pressure increases from impeller hub to blade tip.

With comparison of Fig.2 and Fig.3, it can be found that static pressure on blade front is higher than that on corresponding position of blade back.

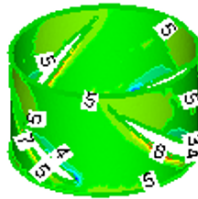
4.2 Relative velocity distributions

According to static pressure distributions of the impeller channel, we can analysis the relative velocity distributions of the blade back and front. Based on Bernoulie's Equation

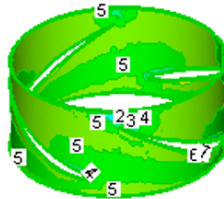
$$\frac{p}{\rho g} + \frac{w^2}{2g} = const \quad (12)$$

The w difference between blade back and blade front exhibits same variation tendency with pressure difference. Assuming uniform pressure distribution at the inlet flow section, then w at two blade sides at the inlet are of the same. As shown in Fig.2 and Fig.3, static pressure increases gradually from blade inlet to outlet, so the velocity w decreases. And it is obvious that w on blade back is higher than that on corresponding position of blade front.

4.3 Gas fraction distributions



(a)Cylindrical flow surface 1($r_1 = 60mm$)



(b) Cylindrical flow surface 2($r_2 = 80mm$)

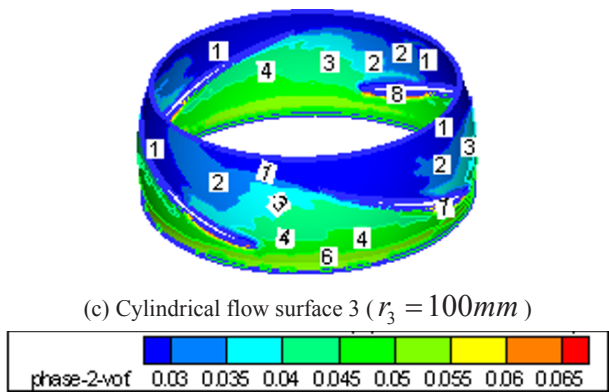


Fig.4. Gas fraction distributions inside the impeller of the axial pump

From Fig.4, we can find that accumulation of air volume happens closely behind the leading edge of the blade back. Along the blades the accumulation became weaker. Along the same axial direction, with the increase of radius, gas fraction decreased. And total gas fraction on blade back is higher than that on blade front. That is decided by the lower pressure regions on blade back. And under action of pressure difference and high speed rotation, fluid flows through flange clearance from blade front to back, air bubbles accumulate here.

5. CONCLUSION

- (1) Commercial CFD technology was successfully applied to simulate the void fraction distributions inside the impeller of an axial flow pump transporting multiphase medium. The results can reflect the flow patterns in the impeller.
- (2) Simulation was carried out at a volumetric air flow rate fraction β at the pump inlet of 5%, a clearly visible accumulation of air was observed at the blade back near the impeller inlet, because the lowest pressure on blade back happens here.
- (3) These results provide useful reference for optimization design of axial flow impeller.

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THE SIMULATION OF AGRICULTURAL NON-POINT SOURCE POLLUTION IN SHUANGYANG RIVER WATERSHED

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Abstract: At present, agricultural non-point source pollution has become an important factor of the water environment deterioration and the lake eutrophication in China. With the Shuangyang River watershed for research object, using GIS and other soft wares establishing the database and the thematic maps of the Shuangyang River watershed, and using AnnAGNPS model simulated agricultural non-point source pollution of the watershed. The results showed that the total pollutant loading time distribution and spatial distribution of Shuangyang River Watershed sources of agricultural nitrogen, phosphorus and sediments. The Application can provide references for theoretical study of the non-point source pollution control and management, as well as practice for this area or domestic other regions.

Keywords: Shuangyang River Watershed, Agricultural non-point source pollution, AnnAGNPS model

1. INTRODUCTION

With people's attention to point source pollution, the point source pollution has been better controlled and managed, rather than non-point source pollution is becoming or has become the main pollution form of impacting water quality (Yang Ailing et al., 1998).Agricultural activities are

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the main reason caused by non-point source pollution. The soil particles, nitrogen, phosphorus, pesticide and other organic or inorganic contaminants in farmland soil, in the course of precipitation or irrigation, through agricultural surface runoff and farmland drainage and underground leakage, flow into the water and lead to water environmental pollution, namely, agricultural non-point source pollution (Liu Jihui et al., 2007). The results showed that, China's chemical fertilizer utilization ratio is not too high, nitrogen utilization of 30% ~ 35%, Phosphorus (P) 10% ~ 20%, Potassium (K) 35% ~ 50%. Even according to the highest utilization ratio to estimate, only in 1995, the loss of nitrogen, phosphorus, potassium respectively reached 13.145 million tons, 5.06 million tons and 13.43 million tons respectively (Peng Kui et al., 2001). Through runoff, eluviations, denitrification, adsorption and erosion unemployed the nutrient flowed into the environment, resulted in water and atmospheric pollution. Therefore, quantitative research on non-point source pollution load not only has an important significance for comprehensive management and systematic research of water environment pollution, but also has significantly environmental and social benefits in our country (Bao Quansheng et al., 1996; Li Guibao et al., 2001).

Shuangyang River originated from Xinyu Village Xinsheng Township Baiquan County of Heilongjiang Province, from east to west crossed Baiquan and flowed into Yi'an County. The segment flowing through Baiquan is the middle reaches of Shuangyang River. The average slope of the river is 0.1%. The watershed located in the open surface of Songnen Plain of the Midwest of Heilongjiang Province, which is the transition zone between extension of Xiaoxinganling mountain and Songnen Plain. It located in 47 ° 12 'N to 47 ° 43'N, 125 ° 32 'E to 126 ° 00'E. The terrain is high on the periphery and low in the middle of the watershed. The surface erosion and gully erosion is developed, so formed interlaced gullies, and showed severe erosion. The earth is highly uneven, the highest altitude is 301.1m, the lowest is 207.1m, and relative difference is 104m in height. The watershed is the severe soil and water erosion area.

2. APPLICATION OF ANNAGNPS MODEL

2.1 Model summary

AnnAGNPS is explored by Agricultural Research Service of USDA, to study the agricultural non-point source pollution load of the watershed. It is a continuous simulation model, compiled by ANSI Fortran95. The model

considers day-to-day weather influence, so not only maintains simplicity of single-event model, also enhances ability of continuous simulation. Based on the digital elevation map (DEM), the AnnAGNPS model automatically defines each cell, the cell in accordance with the water collection region division, so could be arbitrary shape. According to this method to divide unit cell, the characteristics of the watershed itself is completely embodied.

The AnnAGNPS model is mainly composed three components (Darden et al., 2001): (1) Input Data Preparation Model; (2) Pollutant Loading Model and (3) Output Processor Model. The data preparation is the most main step of the model application, the Input Data Preparation Model composed by four modules: Flownet Generator, AGNPS-to-AnnAGNPS Converter, Input Editor, and GEM(Generation of weather Elements for Multiple applications) . The model used the runoff curve equation to calculate surface runoff, the modified universal soil loss equation (RUSLE) to calculate the surface sediment erosion, and the same formula with the CREAMS model to calculate dissolved and particulate concentration of nitrogen and phosphorus.

2.2 The collection of the database

The basic data included graphical, various statistics and experimental data. Graphic data included 1:25000 Watershed DEM map, 1:25000 land utilization map, and 1:250000 soil map which provided by the Earth System Science data sharing network, Heilongjiang Province Bureau of Surveying and Mapping. Statistics data mainly collected rainfall data, population density of the watershed, soil properties included: mechanical composition, organic matter, total nitrogen and phosphorus content, and the other statistical data within the watershed.

2.3 AnnAGNPS parameters selection

AnnAGNPS model system includes 32 classes of factor, about 500 parameters (Cronshey et al., 1998). All the parameters in a unified management by Input Data Preparation Model are stored in data files of AnnAGNPS. For different watersheds, it is not essential to input all parameters, such as livestock point sources, fertilizer and pesticides parameters, and the model also provides a typical value or default value to partial parameters. The main variables and parameters for Model are shown in Table 1.

The model will begin to operate after inputting the parameters in the Input Editor interface of AnnAGNPS model. The operation of AnnAGNPS needs two documents that are AnnAGNPS.inp and Dayclm.inp. Firstly, the two

documents should be placed in the current directory, then run "Execute AnnAGNPS". The model will detect the database, if the detection has error, would display error; if the detection is normal, the model would generate incident files that are AnnAGNPS.evn, AnnAGNPS.acc and AnnAGNPS_AA.dat. The AnnAGNPS.evn file includes the amount of runoff, soil erosion, sediment, nitrogen, phosphorus and organic carbon in the outlet after each rainstorm incident. The AnnAGNPS_AA.dat file includes the annual mount of runoff, soil erosion, sediment, nitrogen, phosphorus and organic carbon in each unit cell. By imported AnnAGNPS_AA.dat, the model generates various *. dbf format files. According to practical need, the output dates of the model can generate the required pollution distribution map.

Table 1. Source of variables and parameters for AnnAGNPS model

Parameter	Source
Geographic parameter	Digital elevation model (DEM)
Soil parameter	《Heilongjiang Soil》
Crop parameter	Guidebook AH-703
Crop cover factor C	Universal Soil Loss Equation
Soil keeping factor P	Consulted data
Runoff curve CN	Data provided by model self :TR55
Climate parameter	Generation by GEM model and correction by climate dates of research region
Manning roughness coefficient and surface conditions	Land utilization situation and Model Guidebook

3. RESULTS AND DISCUSSION

3.1 The total pollution load

The AnnAGNPS model simulation obtained that the Shuangyang River Watershed produced total Nitrogen was 2319.71 tons/year, of which adsorbed nitrogen (Sed. N) 113.67 tons/year, dissolved nitrogen (Sol. N) 2206.04 tons/year, TP for 154.61 tons/year, of which adsorbed phosphorus (Sed P) 79.16 tons/year, dissolved phosphorus (Sol. P) 75.45 tons/year, for the sediment 120893.15 tons/year, including clay 101912.93 tons/year, Silt 18919.78 tons/year, and sand 60.45 tons/year. Its various morphology pollution ratio were shown in [Figure 1](#).

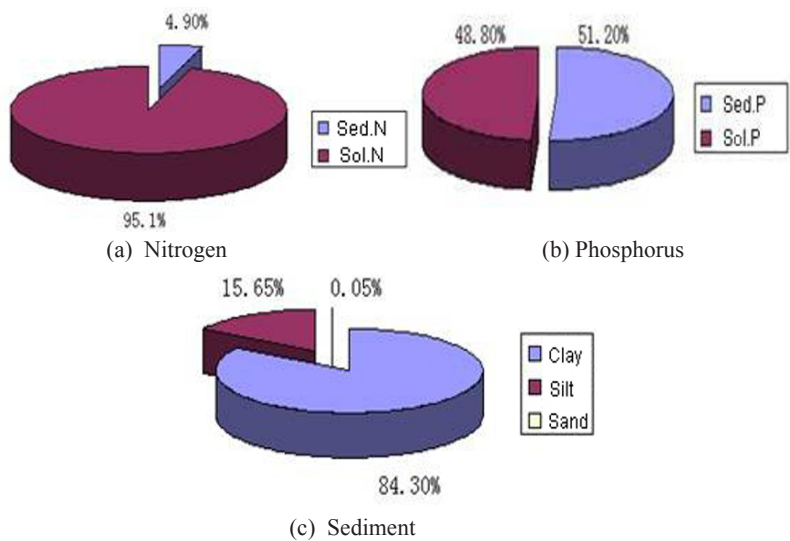
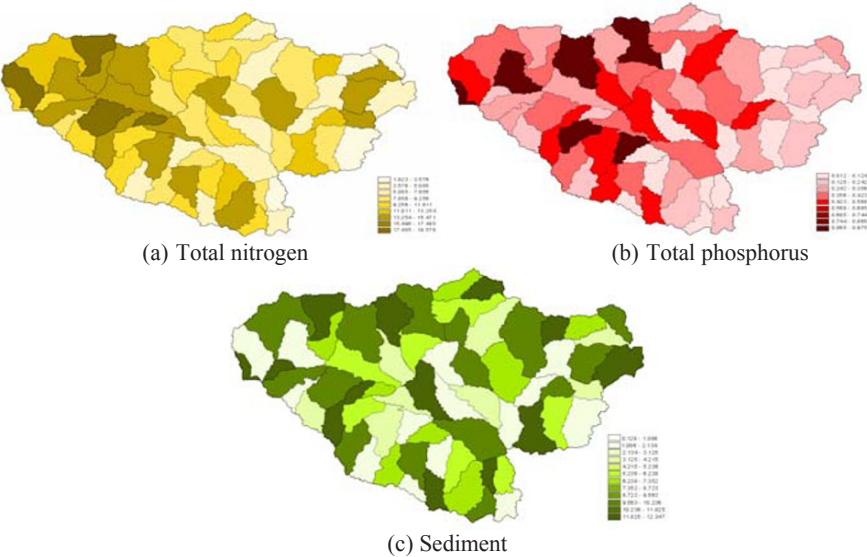


Fig. 1. The proportion of pollution load

3.2 The spatial distribution of non-point source pollution

By means of the output data of the model can generate the pollution load graph. The spatial distributions of total nitrogen, total phosphorus, and sediment were shown in Figure 2.



In the view of the spatial distribution of pollutants, the distributed location of nitrogen, phosphorus and sediment generated from non-point source pollutants is approximate. The pollution in the watershed upstream was relatively serious. Through analyzing topographic map and land utilization map, these areas were slope farmland with steep slope, and forest land cover relatively less, the effect of runoff scouring erosion comparatively significantly, so that basis pollution load will be much more than the normal. In addition, by scouring and leaching of rainfall, sloped farmland more easily separate the soil and nutrients in the soil, resulting in the loss of nutrient and non-point source pollution.

3.3 The time distribution of non-point source pollution

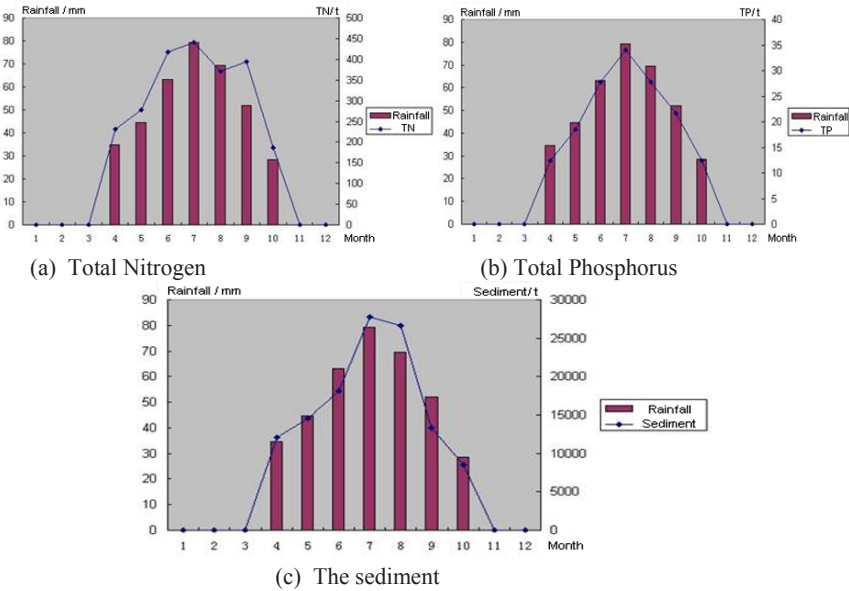


Fig 3: The time distribution of non-point source pollution

Simulating pollution status in one year, the model selected the output amount of total nitrogen, total phosphorus and sediment for index. The simulation results by monthly statistics obtained time distribution of nitrogen, phosphorus and sediment pollution, as shown in [figure3](#).

From the figures, the non-point source pollution is almost no contribution in 1,2,3,11,12 months. In the north area, the rainfall and agricultural activities are rarely in these months. Pollution mainly concentrated on the relatively abundant rainfall summer. The pollution load mainly concentrated in six to eight months, in these three months, the load of nitrogen accounted for 53% of annual load, P accounted for 58% of annual

load, and the sediment accounted for 60% of annual load. Because the local farmers began to apply base fertilizer in May, the fertilizer exposed to the surface, once rainfall occurrence, nutrients will be washing and leaching by rain, along the surface runoff into the river channel. In 9, 10 month non-point source pollution load slightly decreased. Shows that, by strong rainstorm runoff process in the flood season, the nutrient content in the soil has been greatly reduced. But there would still be some nitrogen, phosphorus loss, because from late September to early October, the crop harvest will start in succession, although this period precipitation was less than normal. Owing to the surface vegetation clearly changed, caused soil erosion and nutrient loss. In a word, agricultural non-point source pollution load not only closely related to rainfall, but also to fertilizer application and the surface situation.

3.4 **Model Verification**

The monitoring points of the N, P pollutants concentration in the river were installed in the outlet of the watershed (Meng Dan, 2006). The AnnAGNPS model was verified by the monitoring data. The verification results are showed in table 2.

Table 2 the table of comparison pollution concentration

	TN (mg/L)	error (%)	TP (mg/L)	error (%)
Observation value	2.8561	6.25	0.5913	16.34
Simulation value	3.0347		0.6879	

The results show that AnnAGNPS model for simulations of total nitrogen, total phosphorus load were closed to the measured values, error keeping in the permissible range, and the simulation for the total phosphorus was inferior to the total nitrogen. However, in general, AnnAGNPS model can be applied to evaluate the agricultural non-point source pollution of the Shuangyang River Watershed, and provide valuable reference for making various watershed environmental planning schemes.

3.5 **Controlled measures evaluation**

According to the non-point source status of Shuangyang River Watershed, put forward three different land management measures preventing pollution, and evaluate three measures applicability by AnnAGNPS model.

1. **Land management measure I-** permanent vegetation cover strips

In the watershed main channel boundary set permanent vegetation cover strips (vegetative filter strips), used to intercept sediment and filter chemicals of agricultural surface runoff. When the model simulated this measure, to adjusted AGNPS part of the input parameters including Manning roughness coefficient, surface conditions constant, C factor of USLE equation and size of the grid unit, reflected changes of 20 meters wide vegetation filter.

2. Land management measure II - grassland buffer zone

In watershed all crops area established grassland buffer zone along contour line. These buffer zones had similar function with the last measures filter strips. The difference is not setting in the water boundary. By adjusted C, P factor of USLE equation, the surface conditions constant, Manning roughness coefficient solved the simulation of this measure.

3. Land management measure III- combined method

The method combined vegetative filter strip with contour grassland buffer zone was applied to prevent pollution. The model made suitable adjustment to related input parameters.

By the three land management measures simulation, the results showed that in the watershed outlet reduced percentage of nitrogen output: 28% for measure I , 22% for measure II , 42% for measure III ;to reduce the percentage of phosphorus output: 35% for measure I , 25% for measure II , 53% for measure III; to reduce the percentage of sediment output: 48% for measure I , 42% for measure II , 72% for measure III. Upon those show that the measure III is best effect. The results show that the simulation result is not satisfactory which only setting permanent vegetation cover strips along the river boundary or setting grassland buffer zone along the contour. This conclusion is in accordance with the results which evaluated vegetative filter strips and the grassland buffer zone in conventional methods.

4. CONCLUSION

With the research methods combined with GIS and AnnAGNPS model, forecasted agricultural non-point source pollution of the Shuangyang River Watershed in the Songnen Plain, simulated the effects of the non-point source pollutants production when using different land management measures, and verified the model with measured data. The results show that: the pollution in Shuangyang river watershed upstream was relatively serious. The method combined permanent vegetation cover strips with contour grassland buffer zone can effectively control non-point source pollution in the watershed. The result predicted is acceptable within error range for measured values. The simulation ability for the total nitrogen is stronger than the total phosphorus. The AnnAGNPS model realized agricultural non-point

source pollution load quantitatively estimation. The model simulation results can provide the basis for non-point source pollution controlled and managed.

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ANNUAL PRECIPITATION SERIES WAVELET ANALYSIS OF WELL-IRRIGATION AREA IN SANJIANG PLAIN

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Abstract: The rapid increase of paddy field acreage has led to widely descending of groundwater table in well irrigation paddy area of low-land in Sanjiang Plain recent years. More and more “hanging pump” and partial over pumping phenomenon have been occurring in well irrigation paddy area of low-land. Therefore, the groundwater resources in Sanjiang Plain need to be recharged urgently. For solving the mentioned problems upon, the authors took Farm 853 as an example, analyzed the law of multi-time scale series and characteristics of actual annual precipitation change in Farm 853 through using the wavelet theory, and the main periods of annual precipitation change and variation trend of drought-flood in this area were obviously. The study can provide scientific decision for fully utilizing precipitation, recovering groundwater and sustainable utilization in Farm 853 so much as the entire Sanjiang Plain.

Keywords: sanjiang plain, well irrigated paddy, annual precipitation time series, wavelet analysis, periods

1. INTRODUCTION

Sanjiang Plain lies in the eastern of Heilongjiang province; it is an alluvial plain of Heilongjiang, Songhua river and Wusuri river. The total area is 109 thousands km², the area of cultivated land is 3667.7 thousands hm² (Liang

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[Chunying et al., 2004](#)), and it is an important commodity grain base of China. There is large area of lowland and flatland in Sanjiang plain. The soil of most area is heavy clay which the drainage capacity is low, and easily leads to water logging disaster and yield reduction. From the 1980s, for reclaiming the lowland, many farms had begun to plant rice in Sanjiang plain, to control water logging and the action had obtained significant benefits. During 1981 to 2000, the paddy acreage rapidly increased from 70 thousands hm^2 to 953 thousands hm^2 in Sanjiang plain and mainly is irrigated by well irrigation. The well irrigation paddy was 659 thousands hm^2 in 2000. Owing to the paddy acreage rapidly increased and need to open large quantity of groundwater, the water consumption of well irrigation in Sanjiang plain was 4.56 billion m^3 in 2000. Additionally, the severe water wasting leads to groundwater table decrease rapidly. In Sanjiang plain, the 'hanging pump' and partial overdraft phenomenon often occur, the dynamic equilibrium of groundwater resources in Sanjiang plain has been severe damaged. Therefore, strengthen the study on groundwater recharge of Sanjiang plain is necessary. The precipitation is a main source and an important factor for groundwater artificial recharge. The multi-annual average precipitation is about 560mm, the annual variation of precipitation is great, and the annual distribution is very uneven ([Li Shifeng et al., 2000](#)). Therefore, study on the long term variation characteristics of annual precipitation in the area of lowland, well irrigation paddy, analysis the change law of drought and flood in Sanjiang plain are important for groundwater resources recovery and sustainable utilization.

The traditional methods that study the multiple time scale variation characteristics of precipitation mainly conclude Fourier analysis, Filtering analysis, Time series analysis etc, the study basis of these methods are only for single time scale, haven't the localization properties on both the time and frequency domains, and lack the mathematic rigorous on the diagnosis to the mutation points ([Chen Huailiang et al., 2005](#)), therefore they cannot comprehensively reflect the multiple time scale variation characteristics of precipitation. Wavelet analysis developed from 1980s, which has the time frequency multi-resolution function and strict mutation point analysis function in mathematic significance, it can simplify multiple time scale analysis ([Chen Huailiang et al., 2005](#); [Xu Yueqing et al., 2004](#)), therefore better than all those traditional methods mentioned above and in recent years it has been widely used in the study on the climate multiple time scale analysis. The paper had taken the Farm 853 as a case, used the wavelet analysis theory to diagnose the multiple time scale characteristics of the 47 years precipitation time series of Farm 853, reveal the cycle characteristics of annual precipitation and change trend of drought and flood in the Farm 853, provided the scientific basis for the groundwater recovery and key problems study on regional water saving agriculture.

2. THE BASIC PRINCIPLE OF WAVELET ANALYSIS

2.1 Wavelet function

There are many kinds of wavelet function, often using Marr wavelet, Morlet wavelet and Wave wavelet etc. in the wavelet analysis (Ou Suying et al., 2004; Liu Zhongyang et al., 2005; I. I. I ppolitov et al., 2002; Wang Wensheng et al., 2005). This paper selected the Morlet wavelet that is better in both the time and frequency domain locality, the function is

$$\psi(t) = e^{ict} e^{-t^2/2} \quad (1)$$

Where: c is constant, i is imaginary number.

Because Morlet wavelet is obtained by a periodic function though Gaussian smoothing, there is corresponding relationship between its scale factors and the period in Fourier transform: $T = \left[4\pi / \left(c + \sqrt{2 + c^2}\right)\right] \times a$. When take the constant $c=6.2$, $T = 1.00057a \approx a$, therefore the Morlet can be used to periodic analysis.

2.2 Wavelet transformation

Wavelet transformation is the key of the Wavelet analysis. For the Wavelet function $\psi(t)$ given and satisfy some conditions, the constant Wavelet transformation of time series $f(t) \in L^2(R)$ defined as:

$$W_f(a, b) = |a|^{-\frac{1}{2}} \int_{-\infty}^{+\infty} f(t) \overline{\psi\left(\frac{t-b}{a}\right)} dt \quad (2)$$

Where: $W_f(a, b)$ is Wavelet transformation coefficient, a is scale factor, as the length of Wavelet period, and b is time factor, as the translation time. (Liu Zhongyang et al., 2005; Wang Wensheng et al., 2005; Wu Dongjie et al., 2004)

The hydrological time series are mostly discrete in practical application, for example $f(k\Delta t)$ ($k = 1, 2, \dots, n$; Δt is sampling time interval). The formula (2) can be revised (Liu Zhongyang et al., 2005; I. I. Ippolitov et al., 2002; A. Subasi et al., 2005) as:

$$W_f(a, b) = |a|^{-\frac{1}{2}} \Delta t \sum_{k=1}^n f(k\Delta t) \overline{\psi\left(\frac{k\Delta t - b}{a}\right)} \quad (3)$$

Where: $W_f(a, b)$ is a function of time domain parameter and frequency domain parameter, it is the output of filter that the time series of $f(t)$ or $f(k\Delta t)$ response by unit pulse. When a is smaller, the resolution of frequency domain is lower, and the resolution of time domain is higher; when a is bigger, the resolution of frequency domain is higher, and the resolution of time domain is lower. Therefore, the Wavelet transformation can realize time and frequency localization that window size fixed and shape variable.

According to $W_f(a, b)$ changed by a and b , we can draw the two dimensional contour map about $W_f(a, b)$, with b as abscissa and a as ordinate, called the Wavelet transformation parameter map. With analysis of Wavelet transformation parameter map, we can obtain the Wavelet change characteristics that hydrological time series in Wavelet change domain, and reveal the multiple time scale evolution characteristics and mutation characteristics of the hydrological time series.

2.3 Wavelet variance

Wavelet variance is the integration of the square of all the Wavelet transformation parameter about a in the time domain. For the discrete hydrology time series, Wavelet variance can be calculated with the formula (4) (X. C. Mi et al., 2005; Liu Jianmei et al., 2005)

$$Var(a) = \frac{1}{n} \sum_{b=1}^n |W_f(a, b)|^2 \quad (4)$$

Where: n is the number of samples, $|W_f(a, b)|^2$ is module square of Wavelet transformation coefficient.

The wavelet variance change process follows the scale a is called wavelet variance graph, the graph can show the fluctuation of all kinds of scales including hydrological time series and the characteristic of its intensity (the size of energy) follows the scale's change, in the graph each peak value respectively corresponds to each significantly period. Therefore, we can conveniently determine a main time scale (main period) existing in a time series.

3. THE CASE STUDY

The Farm 853 located in the eastern of Sanjiang plain of Heilongjiang province, belonging to Hongxinglong farm management bureau, the total

area of the land is 1168.7 km²; the area of cultivated land among them is 581.35 km². The Farm 853 is a large mechanized state farm which mainly plants wheat, soybean, maize and rice. From 1991 to 2000, the paddy field acreage of the Farm 853 rapidly increases from 6.1 thousand hm² to 26.7 thousand hm² which 72% of paddy is well irrigation rice. According to investigation data of the Farm 853 in the 8 years from 1991 to 1998, the groundwater table descends 0.3m/a. The annual average exploitable capacity of groundwater resources is 0.04186 billion m³/a. However, the amount of exploitation of groundwater resources in 2000 is 0.08046 billion m³, the annual average amplitude of groundwater table descent is 0.3 m/a in recent 6 years from 1999 to 2004. The continuous decrease of groundwater level has severe damaged the balance of local groundwater resources. In order to save the groundwater resources and realize the sustainable development of groundwater resources, this paper set the Farm 853 as an example, according to the wavelet analysis theory mentioned above, the multiple time scale analysis for measured series of annual precipitation data in Farm 853 has been analyzed and know the detail structure and change trend in different time scale.

3.1 Data collection and treatment

The data of annual precipitation from 1959 to 2005 ($n = 47$) have been collected from the meteorological observatory in the Farm 853. For treatment convenient, the measured sequence data of annual precipitation was anomaly treated (that is centralization), and drew the curve of annual precipitation series, see figure 1.

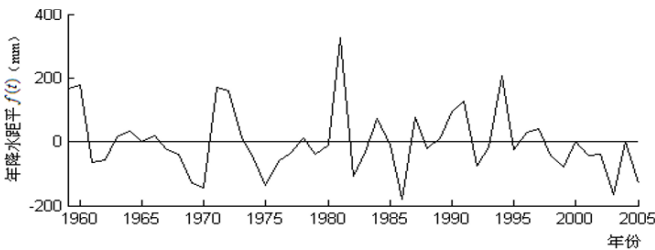


Fig.1 The annual precipitation curve of Farm 853 from1959 to 2005

3.2 Wavelet transformation of annual precipitation anomaly sequence

According to the method mentioned above, the wavelet transformation coefficient $W_f(a, b)$ of annual precipitation anomaly sequence $f(k\Delta t)$ ($k=1, 2, \dots, 47; \Delta t=1$) in the Farm 853 has been calculated.

Because the Morlet wavelet belongs to complex wavelet, its wavelet transformation coefficient concludes the real part and deficiency part. Learn from the literature (X. C. Mi et al., 2005, Zhang Shaowen et al., 2004; Cui Fenglin et al., 2000), the module square of wavelet transformation is proportional to the energy that the function $f(t)$ in its wavelet transformation domain, $|W_f(a, b)|^2$ is wavelet spectrum energy when

signal is at a, b , therefore the module square of wavelet transformation can be used to represent the energy intensity of the characteristic time scale signals. However, the message of the distribution and phase two aspects that different characteristics time scale signals showed in different time can be represented by the real part of wavelet transformation. Therefore, the module square and real apart of wavelet transformation coefficient $W_f(a, b)$ of annual precipitation anomaly sequence implicates the characteristics messages that the sequence changed by the time scale a (namely periodic T) and time shift.

3.3 Time and frequency analysis of annual precipitation anomaly sequence

According to the methods mentioned above, drawing the module square (see figure 2) and real apart (see figure3) contour maps of the wavelet transformation coefficient of the Farm 853 annual precipitation anomaly sequence, and analyze the time and frequency change of annual precipitation anomaly sequence.

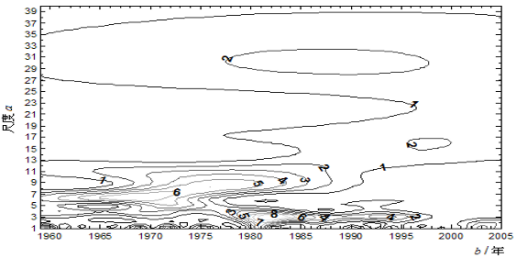


Fig.2:The wavelet transform coefficients modulus square ($\times 10^4$) isoline of annual precipitation anomaly series of Farm 853

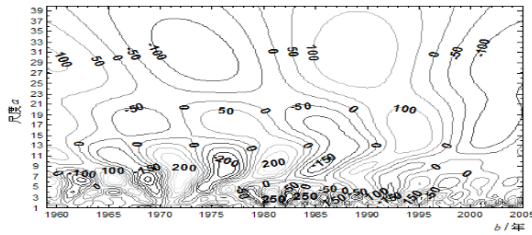


Fig.3: The wavelet transform coefficients real part time-frequency distribution of annual precipitation anomaly series of Farm 853

3.3.1 The time and frequency analysis of wavelet transformation coefficient module square

The intensity of energy distribution of different time scale signal can be seen as Figure 2, in which the energy change of 2~4 years time scale signal is the strongest, occurred from 1978 to 1996. The oscillation center is about 1981; the energy change of 4~12 years time scale signal is stronger, mainly occurred from 1959 to 1988, the oscillation center is near by 1971; the 25~37 years time scale signal mainly occurred from 1959~2000; the 1~2 years time scale signal mainly occurred from 1959~1961, 1968~1973, 1974~1977, 1982~1985 and 1987~1993; the energy change of the other stages time scale signal are weaker.

3.3.2 The time and frequency analysis of wavelet transformation coefficient real part

The change of different time scale, the distribution of catastrophe points and its phase structure as shown in the Figure 3, the time scale of 1~4 years, 4~12 years and 25~37 years represent the most obvious, positive and negative phase appeared alternative, its central time scales are about 3 years, 7 years and 30 years respectively. In addition, the 12~21 years time scale also has representation, its central time scale is about 17 years. In order to show the fluctuation characteristics that drought and flood of the Farm 853 annual precipitation anomaly sequence changed alternative, fixed the value of the time scale a (respectively =3, 7, 17, 30), made a cutting line paralleled with the axis b , and took a point on the cutting line, made the hydrograph that the real part (expressed as $R[W_f(a, b)]$) of wavelet transformation coefficient $W_f(a, b)$ changed with the time shift b , see Figure 4.

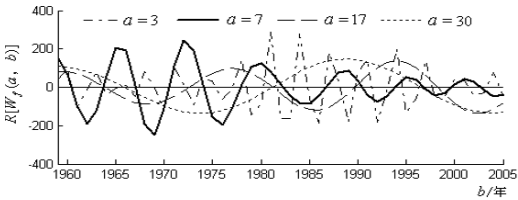


Fig. 4: The Morlet wavelet transform real part variation course of annual precipitation anomaly series

The figure 4 shows that the real part change process of wavelet transformation coefficient of different time scale, now take the 7 years time scale for an example, analyze the drought and flood change of precipitation and the location of the transformation points of positive and negative phrase. According to the real part change process of wavelet transformation coefficient of different time scale in the figure 4, obtained a conclusion that before 1960, 1964~1967, 1971~1974, 1978~1982, 1987~1990, 1994~1996, 2000~2002 are positive phase, which express the abnormal large amount of rain; from 1961~1963, 1968~1970, 1975~1977, 1983~1986, 1991~1993, 1997~1999 and after 2003 are negative phase, which express the abnormal small amount of rain; 1961, 1964, 1967, 1970, 1974, 1978, 1982, 1987, 1990, 1994, 1997, 2000 and 2003 are the catastrophe point of drought and flood.

3.4 Main period analysis of annual precipitation sequence

The main period of the annual precipitation sequence of Farm 853 changed with the time can be studied by the wavelet variance. According to the methods mentioned above, using the wavelet transformation coefficient has solved in different scales, and by means of computer programming, draw the wavelet variance of annual precipitation anomaly sequence, see figure 5. Seeing from the figure 5, the main peaks of wavelet variance respectively occurred at the point which the scale a equals to 3, 7, 17 and 30, the first peak is the wavelet variance which the scale $a=3$ corresponds to, shows that the period about 3 years oscillated strongest, it is the first main period, the second, the third and the forth main period is 7 years, 30 years and 17 years respectively.

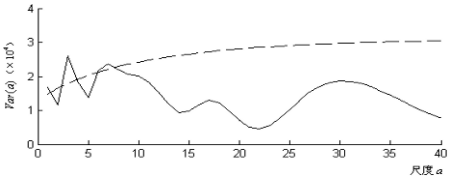


Fig. 5: The wavelet variance of annual precipitation anomaly series in Farm 853 (solid line is wavelet variance, dashed line is 95% confidence level)

3.5 The trend analysis of annual precipitation sequence change

Figure.4 has given the real part change process of the wavelet transformation coefficient in each main period, the change trend of precipitation of the Farm 853 in different time scale can be analyzed by means of the figure 4. From the trend analysis of the change of smaller scale 3 years and 7 years and the bigger scale 17 years. It shows that from 2006 to 2007 the precipitation of the Farm 853 was on the less side, after 2008 is the stage that precipitation is on the high side; from the trend analysis of the change of 30 years scale, we can see that from 2006 to 2011 the precipitation of the Farm 853 is on the less stage, however in the 15 years after 2012, the precipitation of the Farm 853 is on the high stage.

4. CONCLUSION

Wavelet analysis can unfold the fine structure of the hydrological time sequence, and offer a new way for analysis the change characteristics and mutation characteristics of the multiple time scale of the hydrological time sequence.

The annual precipitation sequence of the Farm 853 may has 3 years, 7 years, 17 years and 30 years altogether four main periods was recognized by wavelet analysis, in the four main periods only the 3 years and 7 years main period are obviously and the main periods of 17 years and 30 years has not been clearly.

Through wavelet analysis, the change trend of precipitation of the Farm 853 was roughly opened out, we can use fully the rain and flood resources in the stage of precipitation on the high side to artificial recharge groundwater, speed up the recovery of groundwater resources, thus realize the sustainable utilization of local groundwater resources.

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MODELING AND SIMULATION FOR A VARIABLE SPRAYER RATE SYSTEM

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Abstract: Variable spraying technology is an important content and developing direction in current plant protection machinery, which can effectively save pesticide and lighten burden of ecological environment in agriculture according to characteristic of spraying targets and speed of aircraft crew. Paper established mathematic model and delivery function of variable spraying system based on designed hardware of variable spraying machine, making use of PID controlling algorithm to simulate in matlab. Simulating result explained that the model can conveniently control gushing amounts and can arrive at satisfied controlling.

Keywords: spraying system; variable spraying; matlab simulation

1. INTRODUCTION

So far, although biological measures for crop protection has attracted more attentions, chemistry prevention is still the fastest and most economical cure measure for disease and weeds. Using routine spraying machine to spray pesticide is the most common spraying technology, but the entire field

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has been continued splashing in the process of spraying which has not only brought about pesticide waste, but also brought about environmental pollution.

Lots of scholars have carried out a large quantity of study to reduce pesticide deposition outside targets and improve utilization rates of spraying medicine both at home and abroad. D.K. Giles et al.(1997) have developed a kind of machine system that can spray for targets in line. The optic guiding device of the system controls sprayer to locate above the crop, and the mechanical member which controlled by electric power has made the sector sprayer go round central shaft rotate in order to change deflection angle for sprayer. These measures ensured that the fog droplet distribution width could consistent with crop width to cover with the crop commendably, and decrease pesticide waste and environmental pollution. Sadjadi et al. (1997) have invented a kind of real time identification machine about weed, which can spray targets by actuating mechanism; Doruchowski et al. (1998) has developed a kind of spraying machine system which can selectively spray crop in orchard and field; Slaughter D.C. et al. (1999) have developed a kind of machine system for target which can spray pesticide for trees on roadway, and the system is composed of a machine optic system which has a rapid response. The sprayer can selectively spray according to the allocation. Rongben Wang et al. (2001) have designed a kind of intelligent machine system about fertilizing maize based on computer vision. The system can make science decision for spraying dosages of pesticide by building state image database in the process of corn growth and corn growth process image information which has been collected real time and using the computer expert decision-making system, so that it can complete spraying assignment by automation navigation of tractor and of auto control discharging machinery. Maocheng Zhao et al. (2003) have designed the variable spraying control system based on characteristic image which can precisely spray medicine for targets of tree. According to the growth characteristic of different kinds of tree, planting density and the handling resultes of the crown images of a tree, the computer controls sprayer to carry out spraying on targets accurately. Xiongqui He et al. (2003) have designed a kind of automatic electricity spraying machine of orchard which adopted infrared sensing technology to probe targets. In this system, continuous traditional spraying was changed to the automatic toward-target spraying.

Being compared with and routine large area spraying machine, automatic spraying methods to targets can effectually decrease dosages of pesticide and increase rates of droplet deposition about targets crop. Because the flow rate about spraying system is constant, it can gain comparatively good prevention and cure effect under less condition of change of spraying target characteristic and the aircraft crew speed. But it is difficult to guarantee spraying

result under more condition of change of spraying target characteristic and the aircraft crew speed.

The author designed a variable spraying system in order that we can independently adjust spraying dosages according to characteristic change of spraying objects and change of aircraft crew speed. At the same time, the fog droplet dimension and spraying distribution mass do not change. The system consists of machine optesthesia system and variable spraying system. The paper established mathematic model of variable spraying system based on designed variable spraying system, adopted PID control algorithm to simulate for the model by matlab and got more satisfied controlling result.

2. OPERATING PRINCIPLE OF VARIABLE SPRAYING SYSTEM

CCD telecamera was been assembled in front of spraying machine in order to get image information of spraying targets. We adopted radar sensor to measure speed signal of an aircraft crew. Implantation computer handled picture signal gained and speed signal in real time, and the handled result is given to the controller which controlles entering liquid switch action of every shower unit about spraying system respectively so that it can realize independent variable spraying of every spraying element.

Every spraying element is composed of 3 electromagnetic valve and 3 standard sprayer which have different spraying amounts. These sprayers are assembled on spraying poles of spraying machine. The 3 electromagnetic valve control every sprayer respectively and the stress of sprayers is determined by electro-hydro proportion relief valve. According to handled result, the computer sends out “on” and “off” signal for every electromagnetic valve by I/O module. Different combination of 3 electromagnetic valves can realize 8 combination of working state. So we can realize 7 spraying amounts.

3. MATHEMATIC MODEL OF THE VARIABLE SPRAYING SYSTE

3.1 Establish mathematic model of electromagnetic valve

The following elements are neglected in establishing model: loop resistance coefficient; loop magnetic leakage; changes about medium

magnetic induction; effects of the system resistivity and effects of magnetic inductivity on temperature.

The equilibrium equation:

$$m\ddot{x}_v + c\dot{x}_v = K_F i^2 - k(x_v + x_0) \quad (1)$$

$$\text{In the equation: } K_F = \frac{N^2 \mu \times 10^7}{8\pi[l_H + 2\mu(x_{v\max} - x_v)/\mu_0]}$$

$$\text{Magnetic loop equation: } iN = Hl_H + H_0\delta = Hl_H + H_0(x_{v\max} - x_v) \quad (2)$$

$$H\mu = H_0\mu_0$$

Electric current equation:

$$\begin{cases} u_c = R_L i + \varepsilon_L & 0 \leq t \leq t_p \\ (R_L + R + R_D)i + \varepsilon_L = 0 & t_p \leq t \leq T \end{cases} \quad (3)$$

$$\text{Magnetism equation: } \phi = s_0 \mu_0 H_0 = s_0 \mu H \quad (4)$$

$$\varepsilon_L = N \frac{d\phi}{dt}$$

$$\text{Induced E. M. F equation EMF:} \quad (5)$$

(2), (4) and (5) has been finished and linearized, the result is as follows:

$$\varepsilon_L = K_i \frac{di}{dt} + K_x \frac{dx_v}{dt} \quad (6)$$

$$\text{In the equation: } K_i = \frac{N\phi}{i} = L;$$

$$K_x = \frac{H_0^2 s_0 \mu_0}{i}$$

The result is the following equation:

$$\begin{cases} m\ddot{x}_v + c\dot{x}_v = K_F i^2 - k(x_v + x_0) \\ u_c = R_L i + K_i \frac{di}{dt} + K_x \frac{dx_v}{dt} & 0 \leq t \leq t_p \\ x_v(0) = 0 \quad ; \quad i(0) = 0 \\ \dot{x}_v(0) = 0 \quad ; \quad \ddot{x}_v(0) = 0 \quad ; \quad \dot{i}(0) = 0 \end{cases} \quad (7)$$

$$\left\{ \begin{array}{l} m\ddot{x}_v + c\dot{x}_v = K_F i^2 - k(x_v + x_0) \\ (R_L + R + R_D)i + K_i \frac{di}{dt} + K_x \frac{dx_v}{dt} = 0 \quad t_p \leq t \leq T \\ x_v(0) = x_{v\max} \quad ; \quad i(0) = \frac{u_c}{R_L} \\ \dot{x}_v(0) = 0 \quad ; \quad \ddot{x}_v(0) = 0 \quad ; \quad \dot{i}(0) = 0 \end{array} \right. \quad (8)$$

(7) and (8) has been transformed by Rumsfeld and gained following results:

$$\left\{ \begin{array}{l} (ms^2 + cs + k)X_v = K_F i^2 - kX_0 \\ U_c = (R_L + K_i s)I + K_x sX_v \quad 0 \leq t \leq t_p \\ x_v(0) = 0 \quad ; \quad i(0) = 0 \\ \dot{x}_v(0) = 0 \quad ; \quad \ddot{x}_v(0) = 0 \quad ; \quad \dot{i}(0) = 0 \\ (ms^2 + cs + k)X_v = K_F i^2 - kx_0 \\ (R_L + R + R_D)i + K_i \frac{di}{dt} + K_x \frac{dx_v}{dt} = 0 \quad t_p \leq t \leq T \\ x_v(0) = x_{v\max} \quad ; \quad i(0) = \frac{u_c}{R_L} \\ \dot{x}_v(0) = 0 \quad ; \quad \ddot{x}_v(0) = 0 \quad ; \quad \dot{i}(0) = 0 \end{array} \right.$$

Parameter meanings in equation:

m: slide valve mass; c: equivalent damp;

k: spring stiffness;

x_v : slide valve displacement;

x_0 : spring compressing amounts in advance;

R_L : coil electric resistance;

R_D : diode electric resistance;

l_H : magnetic materials closed circuit length;

σ : air gap;

s_0 : intercepts area of gap air;

μ : induced modulus of magnetic materials;

μ_0 : air magnetic induction modulus;

Φ : circuit magnetism;

ε_L : Induced E. M. F

- i : the current in the coil;
 N : Coil turns;
 H : magnetic field strength;
 H_0 : air magnetic field intensity;
 k_F : Current-force conversion factor
The electromagnetic valve system consists of two non-linear links:
(1) Square links;
(2) Saturated and close links of Spool displacement, $0 \leq x_v \leq x_{v\max}$;

The transfer function block diagram were gained when the electro-magnetic valve opened and closed by equation (7)and (8), figure 1 and figure 2 are as follows:

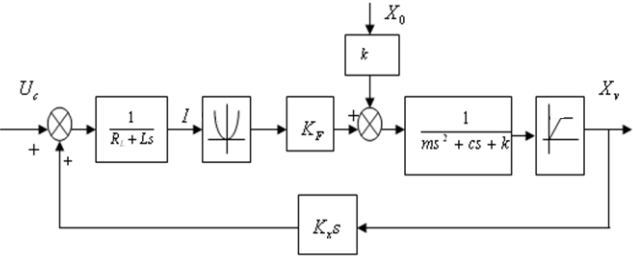


Fig.1: The transfer function block diagram when the electromagnetic valve is closed

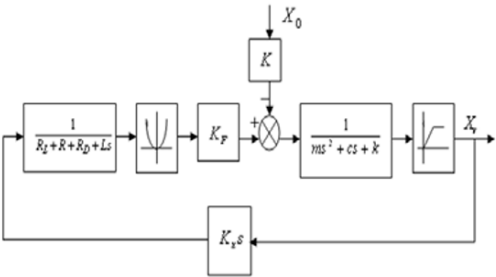


Fig.2 The transfer function block diagram when the electromagnetic valve is opened

Opened process of electromagnetic valve has been simulated by making use of MATLAB software, figure 3 was the simulation results. Transition process response time of opened process about electromagnetic valve was about 0.11s and equivalent to 9HZ, which can meet the system requirements of object. The two nonlinear part of electromagnetic valve system were almost no impact to response from simulation result. In fact, electromagnetic valve can avoid nonlinear effect if electromagnetic valve is took appropriate control. It will not have aborting and saturation phenomenon if we control spool within the scope of work. Nonlinearity of square category can be overcome by adopting small range linearization or method of inserting value.

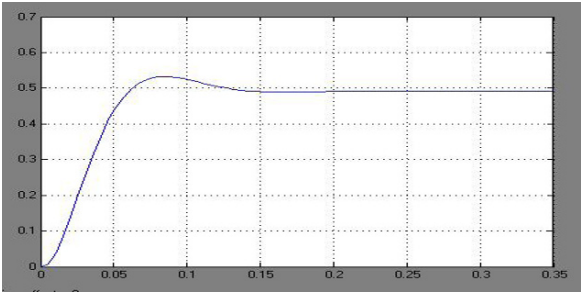


Fig.3 Response curve electromagnetic valve is opened

3.2 Establish mathematic model of variable spraying system about level

Dynamic response frequency of proportional valve pilot stage is very high, proportioning valve for response frequency under 10Hz can be regard as a proportional component (Yongxiang Lu, 1987). Delivery function block diagram of electro-hydro proportion relief valve is figure 4.

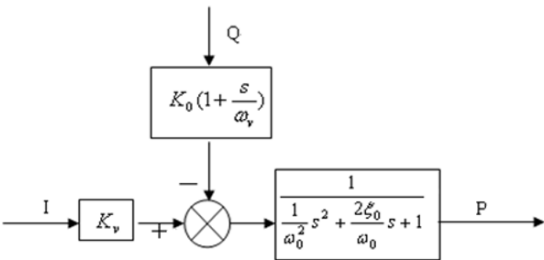


Fig.4 Delivery function block of electro-hydro proportion relief valve

According to operating principle of automatic level variable spraying system, the shower nozzle consists of three closure devices of different fixed damming mouth, taking $Kq=0$ and regarding other parameters as modulus of equivalent mass, equivalent damp, equivalent spring stiffness, equivalent effective area, and equivalent pressure rate of flow after different shower nozzle combination. Equivalent block diagram of delivery function about shower nozzle is figure 5.

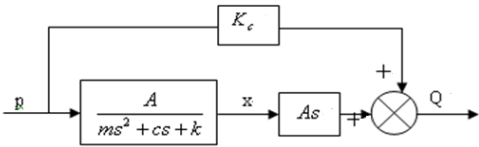


Fig.5 Equivalent block diagram

According to operating principle of level automatic variable spraying system, results are as follows:

(1)Actuating pressure of shower nozzles is decided by electricity liquid proportion valve, therefore, entrance pressure change of shower nozzle (outlet pressure is 0) is same to output pressure of electricity liquid proportion valve.

(2)It gives medicine pump to a part of export the rate of flow, and another part floods by electricity liquid proportion valve. Flow rate of shower nozzle will increase if outputting flow rate of medicine pump is invariable, which means flow rate of that electricity liquid proportion valve floods will decrease. In a word, change amounts (increasing amounts and decreasing amounts) are equal.

According to above analysis, lock diagram of entire system was gained by linking with figure 4 and figure 5, block diagram of entire system is figure 6.

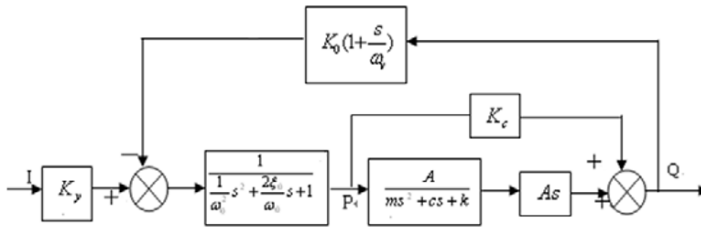


Fig.6 Block diagram of level variable spraying system

4. SIMULATION RESULTS AND ANALYZING OF SYSTEM

Simulating model is figure 7 when a spraying shower nozzle works.

Step response result is figure 8 by matlab simulating. When the steady state accuracy of system is 2%, response time of transition process is 0.208s, surpassing amount of system is 10%. Analyzing result of system frequency is figure 9. The system is stable, and bandwidth is 44.5rad/sec, about 7Hz, which is consistent with frequency of proportion flooding valve. It explained that characteristic of proportion flooding valve decides entire systematic characteristic and system is able to satisfy actual request.

Front passage of delivery function from P to Q about delivery function changed when 2 and 3 shower nozzles worked. In a word, delivery function of 2 or 3 shower nozzles were overlayed. Denominator of the delivery function after overlying does not change but molecule changes. The systematic characteristic equation does not change for output of systematic general rate flow, the systematic stability, time respond and frequency

respond do not change. The flow rate of output is also different for every shower nozzle because opening aperture amounts are different.

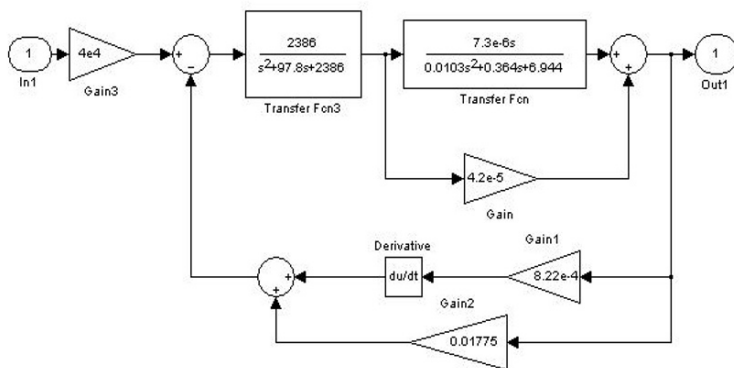


Fig.7 Simulation model of system

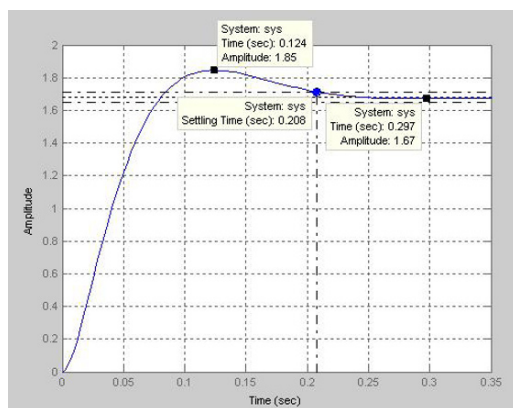


Fig.8 Result of step response

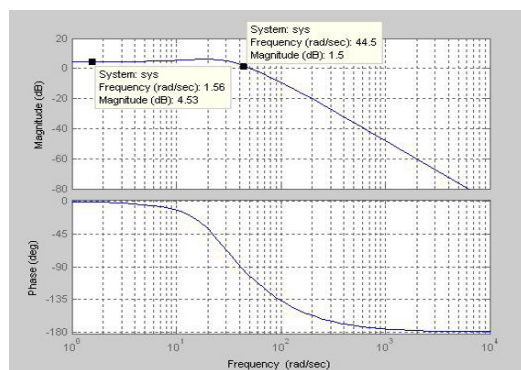


Fig. 9 Analyzing result of frequency

Change mathematic model into state space equation:

$$\dot{X} = AX + BU$$

$$Y = CX + DU$$

In the equation:

$$A = 10^3 \begin{bmatrix} -0.0353 & -0.6742 & 0 & 2.3860 \\ 0.0010 & 0 & 0 & 0 \\ 0 & 0 & -0.1278 & -2.3860 \\ 0 & 0 & 0.0010 & 0 \end{bmatrix} \quad B = 10^4 \begin{bmatrix} 0 \\ 0 \\ 4 \\ 0 \end{bmatrix}$$

$$C = [0.0007 \quad 0 \quad 0 \quad 0.1002] \quad D = [0]$$

Controllable matrix is:

$$P = [B \quad AB \quad A^2B \quad A^3B]$$

$$= 10^{10} \begin{bmatrix} 0 & 0 & 0.0095 & -1.5570 \\ 0 & 0 & 0 & 0.0095 \\ 4 & -0.0005 & 0.0558 & -5.9099 \\ 0 & 0 & -0.0005 & 0.0558 \end{bmatrix}$$

$$\text{rank}(P) = 4 = n$$

It can be seen that system is controllable. Standard form of controllable matrix is:

$$A_c = 10^6 \begin{bmatrix} 0 & 0 & 0 & -1.6086 \\ 0 & 0 & 0 & -0.1705 \\ 0 & 0 & 0 & -0.0076 \\ 0 & 0 & 0 & -0.0002 \end{bmatrix} \quad B_c = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$C_c = 10^7 [0 \quad 0.0004 \quad -0.0445 \quad 4.4871] \quad D_c = [0]$$

Original systematic zeros are -28.83 and -23.38, poles are -17.67+ 19.02i, -17.67-19.02i, -105 and 227, and open loop gain is 4008. Because system is controllable, we can deploy a pole so that systematic function reach expected function. If systematic poles are supposed -5+20i, -5-20i, -25 and -40, feedback matrix will be $K=[0.0001 \quad 0.0045 \quad -0.0022 \quad -0.0597]$. The step response is figure 10 after systematic poles are deployed again. Comparing with Figure 8 and figure 10, we can know that response time will decrease after deploying poles again, but oscillating function is bad. If we hope that

oscillating function is better as well, we can deploy poles again and analyze. Finally, we can gain satisfied results.

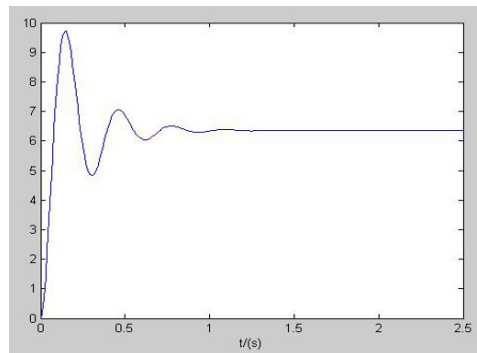


Fig.10 Step response after deploying poles

Observed matrix is :

$$Q = \begin{bmatrix} C \\ CA \\ C^2A \\ C^3A \end{bmatrix} = 10^4 \begin{bmatrix} 0.0001 & 0 & 0 & 0.0001 \\ 0 & 0.0001 & 0 & 0.0002 \\ 0 & 0.0017 & -0.0011 & -0.0299 \\ 0.0002 & -0.0275 & 0.1122 & 2.7495 \end{bmatrix}$$

$$\text{rank}(Q) = 4 = n$$

It can be seen that system is observed. Standard form of observed matrix is:

$$A_o = 10^6 \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ -1.6086 & -0.1705 & -0.0076 & -0.0002 \end{bmatrix} \quad B_o = \begin{bmatrix} 0 \\ 0.0004 \\ -0.0445 \\ 4.4871 \end{bmatrix}$$

$$C_o = [1 \ 0 \ 0 \ 0] \quad D_o = [0]$$

5. CONCLUSIONS

Paper established mathematic model and delivery function of variable spraying system based on designed hardware of variable spraying machine. We used PID controlling algorithm to simulate with matlab. Simulating results explained that level variable spraying system is stable, and when the steady state accuracy of system is 2%, the response time of transition process

is 0.208s, surpassing amount of system is 10%, bandwidth is 44.5rad/sec, about 7Hz, which is consistent with frequency of proportion flooding valve. The system is able to satisfy actual request as well. Controllable nature and observed nature were analyzed for variable spraying system. As a result, system is controllable and observed. We can deploy poles in order to make systematic function reach the best capability according to requirements. Designed system is reasonable, able to satisfy usage request and easy to control.

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RESEARCH ON CROP SIMULATION MODEL BASED ON PDA

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Abstract: Crop model simulates growth and yield of crop in field scale and can be used to provide useful field information for farmers, such as irrigation application dates and amount, fertilizer application dates and amount, the choose of crop variety. Researchers have used crop models for many years, but they have had limited success in packaging these complex models in a framework that make them easy for producers to use. In order to provide an efficient and powerful way for delivering crop models to crop producer, a PDA based crop simulation model is designed and implemented. The paper discussed the structure and key technologies of the PDA based crop model. By using the PDA based crop model, farmers can get quick and effective advices from the model. The PDA based crop models are expected to give a new powerful tool to assess the effect of farm practices in crop production.

Keywords: crop model, simulation, visualization, PDA

1. INTRODUCTION

The research on crop-environment system began in 60's. In the past 40 years, it has got great achievements. It was developed from simulation of the basic procedure of crop-environment system & research of the instantaneous effects to simulation of whole crop-environment system & research of the

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interaction of procedures and accumulated effects(Zhu Yeping et al.,2000 ; N.W.T. Quinn et al., 2004). Crop production, farm management and decision making are influenced by a lot of uncertain factors, such as biological and technological ones. Some important decisions in agricultural production, such as irrigation application dates and amount, fertilizer application dates and amount, the choose of crop variety are depended heavily on the existing knowledge base of current environment conditions like soil and climate, water resource(Wang Shiqi,1998). Even in high production level areas such as Beijing, there were also many factors that could not be controlled by people. In order to reach their goals, producers have to take proper measurements according to the information that they had mastered. With the development of agriculture, yield is not the only target, and utilizing resource more reasonably, gaining high yield and high effect with the least investment is took more and more attentions.

Crop model simulates growth and yield of crop in field scale and can be used to provide useful field information for farmers, such as irrigation application dates and amount, fertilizer application dates and amount, the choose of crop variety(Paz, JO and WD Batchelor, 2003). Crop model is an important tool to make quantitative analysis of the crop-environment system. It can be used in different situations, and can provide various information about the system to different users, especially in providing the agricultural technical personnel with production information. It can be used to predict those factors that could not be controlled. It can help to decide the irrigation measurement and fertilization measurement according to special target such as high yield, maximal profit.

Due to the complexity of crop-environment system, the limit of agricultural data collection and some technology restrictions, crop model techniques have not been widely applied in agricultural production. Researchers have used crop models for many years, but have had limited success in packaging these complex models in a framework that make them easy for producers to use.

In recent years, PDA developed very rapidly. The function of the operating system of PDA was even stronger, and there were several tools supporting PDA application development. It is possible to the development of the agriculture-based Pocket PC applications. In order to provide an efficient and powerful way for delivering crop models to crop producer, wheat and corn crop models based on PDA are designed and implemented. The paper discussed the structure and key technologies of the PDA based crop model. By using the PDA based crop model, farmers can get quick and effective advices from the model. The PDA based crop models are expected to give a new powerful tool to assess the effect of farm practices in crop production.

2. DESIGN OF THE CROP SIMULATION MODEL BASED ON PDA

PDA based crop model is composed of parameter management module, GPS module, simulation module, decision module and visualization of crop growth module. The basic functions of the system are shown as fig 1. The parameter management module is important part of the system as model input. While some parameters are input to model by hand, and some parameters of the model can be acquired with the GPS information. After position information of the simulation place is received by GPS receiver, we can send parameter search request to the backend server, for example, we can send the place position to weather databases to get the weather information.

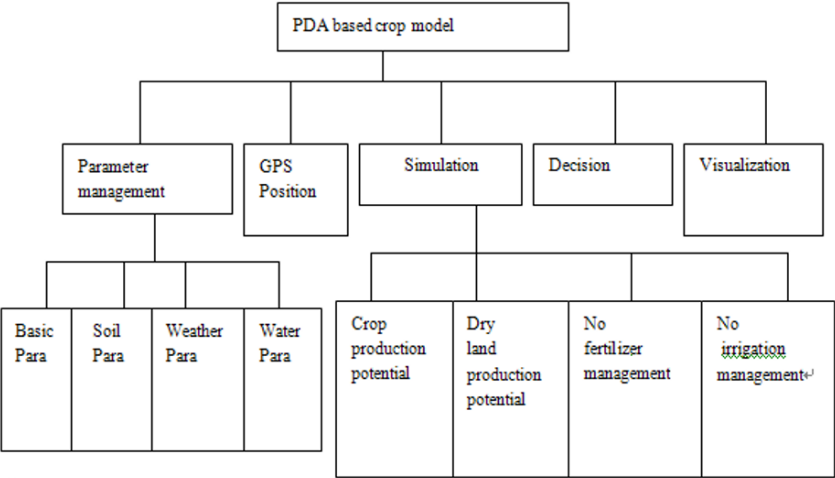


Fig.1: Basic functions of the system

Crop simulation model can simulate in several environments such as crop production potential, dry land production potential, no fertilizer management etc. According to different goals, decision module can provide optimum plant measurement. In order to make uses understand the crop growth stages better, the system provides visible crop growth simulation.

The architecture of the system is based on multi-layers architecture. The system is composed of three layers: the user interface layer, the service layer, and the database layer. The architecture of the system is as Fig 2:

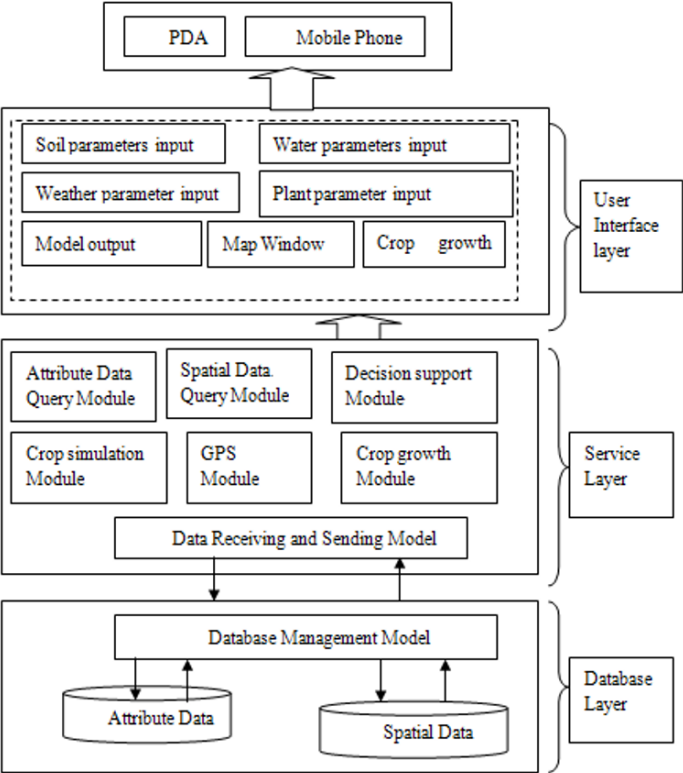


Fig.2: Architecture of PDA based crop simulation system

3. KEY TECHNOLOGIES OF THE SYSTEM

In order to achieve crop production simulation at 4A(anytime, anywhere, anybody, anything), the system applies embedded programming technology, GPS technology, database technology, crop growth visualization and crop simulation technology. The integration of GPS technology makes parameter acquiring more convenient. The database technology in PDA makes data management easy and effective. The visualization technology of crop growth makes users understanding easily.

3.1 Integration of GPS positioning

GPS module is responsible for accepting GPS data. By serial communication programming, the current position coordinate can be acquired and parsed in the system. The basic units (water, soil and weather data) of crop models have a spatial distribution. Spatial variability of crop production

such as different soil conditions, weather conditions and water conditions needs different agricultural production management practices within a target-region. With the position coordinate, we can get the spatial information and property information of the current field. With the combination of GPS technology, some model inputs can be imported to the system and we need not to input every model parameter in the system. And also GPS position can be integrated with GIS functionalities, they will provide more conveniences for crop simulation and analysis.

3.2 Crop simulation model

Crop simulation model is the key part of the system. It is the result of many years' research in wheat and corn simulation by Yeping zhu, Shiqi wang in CAAS(Chinese Academy of Agricultural Science). The research was supported by Chinese Academy of Agricultural Science and National 863 project of China. The models require inputs including environmental conditions (soil type, daily maximum and minimum temperature, rainfall, and solar radiation) and management practices (variety, row spacing, plant population). The simulation result includes daily growth of vegetative, stage, and water and nitrogen stress. The model provided decisions and supports to the below practical questions: the choose of spices in wheat-corn continuous cropping condition, the reasonable use of the resource, best use of the limited water resource, distributing the limited N fertilizer to maximal profit. In our research we focuses on the migration of crop models from Windows desktop to WinCE.

3.3 visualization of crop growth

The visualization of crop growth includes the visualization of root, stem, leaf and grain. The shape of single crop is displayed on the screen everyday according to the result of the simulation. In order to implement visualization of the crop during growth stage, we adopt object oriented programming. We designed CRoot, CLeaf, CLitter, CGrain classes. Every class is responsible for its visual expression. The whole crop visual expression is composed of all its parts. During the visual expression of crop growth, firstly we got the leaf, root, litter and grain parameter values, then put those values to relative object of correspondent class. Then the dynamic growth process can be displayed. The visibility technology of crop growth makes the model more conveniently to use.

3.4 Database

The development of this system is based on Windows CE operating system. Currently the database can be used on Windows CE includes Pocket Access,

SQL Server CE, Oracle Lite and so on. Since SQL Server CE has been able to implement most of the SQL query processing, support for most of SQL statements, and made a lot of optimization to accelerate the speed of the implementation of SQL statements, we choose to use the SQL Server CE to store model parameters and output.

There are three kinds of database development technologies in Windows CE platform: using database application programming interface (API) provided by Windows CE, using ActiveX Data Objects (ActiveX Data Objects, ADO) interface or use OLEDB interface. Considering development of difficulty and speed of response, we choose to use ADO CE development technology. Crop simulation database includes basic parameters table, irrigation data table, fertilization table, the weather data, soil parameters table, crop varieties table and so on.

4. IMPLEMENTATION

The PDA based crop simulation system is developed under the condition of Windows CE desktop, the local database is adopt SQL server CE, and the development tool is Microsoft Windows CE Toolkit for Visual C++(eVC). ADOCE technology is used in the system to access database. GPS module programming uses serial communication technology. After receiving the data from the COM port, it should be parsed to get the position coordinate. The visualization of crop growth used object oriented design and implementation.

Some of running results of the system are as follow:

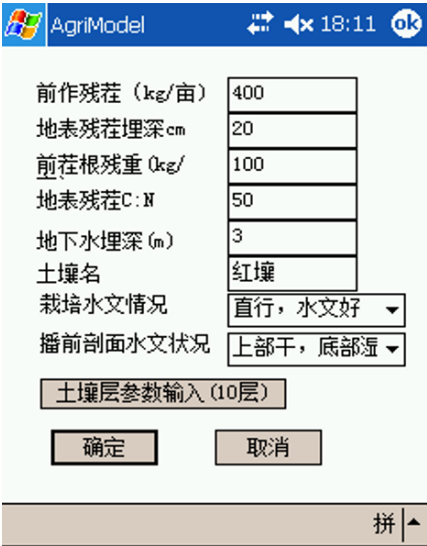


Fig. 3. Soil parameter input interface

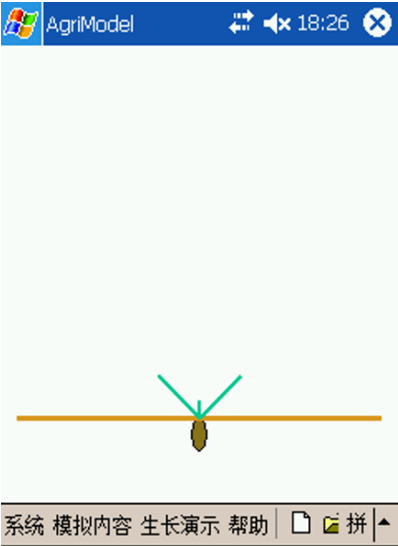


Fig 4. Main interface of the model

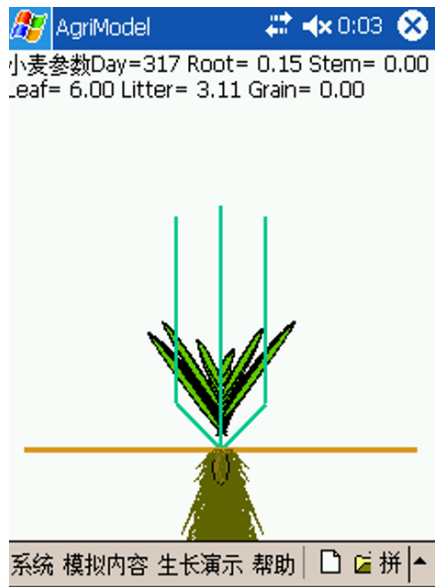


Fig.5 Visualization of crop growth(Day=317)

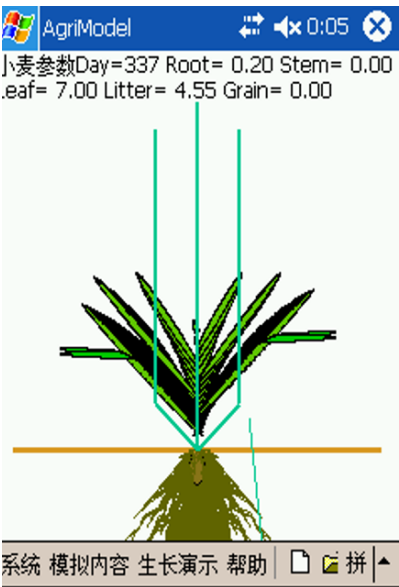


Fig.6 Visualization of crop growth(Day=317)

5. CONCLUSION

PDA based crop models are expected to give a new approach to provide agricultural managers with a powerful tool to assess simultaneously the effect of farm practices to crop production. In this study, a system framework is designed using three-tier architecture, and crop models are packaged and migrated to PDA. The graphical display of wheat and corn model results, visualization of crop growth and decision of crop production are also achieved in the system. The study successfully demonstrated the integration of crop model with embedded technology, GPS technology and its application in crop production management. With the support of embedded technology, crop models will be easy to use in crop production.

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CALCULATION OF RESOURCES CARRYING CAPACITY BASED ON ECOLOGICAL FOOTPRINT IN BEIJING MOUNTAINOUS AREA

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Abstract: The issue uses ecological footprint method to research 7 target counties of Beijing and gains the per capita ecological deficit after 12 percent areas deduction for biological diversification. We found that target region has a magnified trend of ecological deficit and then, we try to offer some proposals about how to develop the mountainous counties.

Keywords: Beijing mountainous county, ecological footprint, resources carrying capacity, ecological deficit

1. INTRODUCTION

According to ‘the eleventh five-year plan’ of Beijing and ‘The overall urban planning of Beijing (2004-2020)’, Beijing mountainous areas are classified as Ecological Conservation Regions. The progress of mountainous areas is favor for constructing a comprehensive construction well-off society, expanding the domestic market, and humanizing the development of urban and county.

Mountainous areas are the ecological conservation regions, protected field of wellspring, civic leisure place and ecological protective screen for maintaining benign environment of Beijing. These areas have already carried

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on several ecological conservation region projects to protect and renovate ecological resources, which in turns play a very important role in improving ecological environment of Beijing that securing realization of Green Olympics idea. Three types of leading industries, special forest fruits, green farm, ecological tourism, have been developed very well, satisfying citizen's growing needs for being health, going back to nature, as well as enjoying the agriculture for resting and so on. Therefore, it is meaningful for new counties construction in mountainous areas.

Quantitative measurement for calculating regional resources carrying capacity has already become very important in recent years. Carrying capacity conception origins from ecology, meaning 'The organism numbers a community could carry based on the existing resources.' We can analyze the regional resources environment capacity according to two rules, 'the speed of social production can not exceed the speed of earth's decomposition and reproduction.' and 'materials basis of productivity and biological diversity can not be damaged', from the view of sustainability. As for quantitative evaluation for resources and environment carrying capacity, there have been many researches in the world and a serious of index and methods are available. Among them, ecological footprint is developed comparatively fast. It is created by Canadian professor William Rees in 1992(William ER, 1992), soon later he and his student Mathis Wackernagel introduced how to use it for calculating in details(Wackernagel M, William ER. 1996) and gained ecological footprint in 52 countries and areas. Internal scholars have tracked the ecological footprint method. These researches include static analysis in a certain point of time, like calculation and conclusion of ecological footprint in Zhangye district, 1995, Gansu province, 1999(Zhongmin Xu, Zhiqiang Zhang, Guodong Chen. 1996) and dynamic analysis in certain regions at certain time, taking China ecological footprint during 1978-2003 (Min Chen, Lijun Zhang, Rusong Wang, 2005), and supply and demand of ecological footprint since 'Reform and Opening' (Xiaoqing Zhong, Yongliang Zhao, Shan Zhong, 2006). These researches covered several levels of county, region, and city, hoping to find the effects of human beings on the local biosphere. However, there have not many researches referring to counties by far. This issue is planning to apply ecological footprint method to the research of countryside ecological carrying capacity calculation, measuring the supply and demand for ecological footprint based on the consumption and production, and then judge whether counties are in ecological surplus or deficit. Moreover, from this judgment, we will find rural population's effects on the biosphere, and try to offer a new research method for analyzing the resources carrying capacity for new county construction.

2. CONCEPTION, CONNOTATION, MODEL AND CALCULATING STEPS OF ECOLOGICAL FOOTPRINT

2.1 Concept Connotation of Ecological Footprint

Biosphere that human depend on not only offers various materials for human living, such as biological and energy resources, but decomposing place for all the waste coming from human consumption. Whether biosphere could play its role and being used forever depend on whether effects of human activities are within biosphere's hold value. Ecological footprint means how many biological productive land areas are needed for maintaining resources consumption along with waste absorption under a certain population, consumption level, and economical condition. It is used to evaluate effects of human activities on biosphere, whose essence is to change the compare between supply and demand of regional resources into compare between supply and demand of land, which could be gained through calculation of ecological footprint and ecological carrying capacity of target region. The hold value of biosphere is called ecological carrying capacity. The result of compare between ecological footprint and ecological carrying capacity (ecological surplus or ecological deficit) indicates whether human use biosphere excessively.

Calculation of ecological footprint is based on following assumptions: (1) the consumption data of regional biological and energy resources, namely detailed statistics of residents' consumption in target region is available; (2) the majority biological resources production consumed by people in target region and waste from biological and energy resources consumption can be converted into certain areas of land; (3) giving weight to each type of land (equivalence factor and yield factor), transfer it into a standardized global unit with world average production ability so that world compare is possible; (4) each type of land use is exclusive, therefore the total demand can be gained by plus the areas of resources use and waste absorption; (5) the total land supply is the current land use condition in target region in a certain time; (6) through comparing the total supply and demand, we can find the human effects on biosphere. Ecological surplus implies that effects are within hold value, and ecological deficit implies human effects exceed hold value, which is unsustainable.

2.2 Model of Ecological Footprint calculation

Human's producing and living consumption is made of ecological resources consumption and energy consumption. Ecological resources can be divided into produce, animal product, fruit, and wood. Energy consumption includes: coal, electric power and so on. In the rural areas, residents get their food main from local place, but their energy consumption depends on outside production, of course to some extent depends on local biological productivity, like stalks and firewood. This issue assumes that rural biological resources consumption is satisfied by local production and there is no interregional exchange, while the demand for energy consumption is totally covered by outside import. In the ecological footprint model, the main effects of energy consumption on region are exhausting gas' assimilation produced by human consumption. There is no influence by using ecological footprint method.

All the consumption items researched by ecological footprint method are classified into six types of biological productive areas, cultivated land, forest land, grass land, building site, fossil energy land and waters. The conception of biological productive area is a standard for measuring various natural resources. Because of different ecological productivity of these six types lands, in order to shift them into lands with the same biological productive area so that we can calculate the sum of them to find the ecological footprint and ecological carrying capacity, each type of biological productivity should multiply an equivalent factor, which is used to describe a certain land's potential biological productivity with given input (such as water and fertilizer), but not considering current management. Equivalent factor of a certain type of biological productive area is equal to the ration between average ecological productivity of this type all over the world and average ecological productivity of all the biological productive areas in the world. Current using equivalent factor is 2.8 for cultivated land and building site, 1.1 for forest and fossil energy land, 0.5 for grassland and 0.2 for ocean. 2.8 implies ecological productivity of cultivated land and building site's biological productive area is two times the global ecosystem's average productivity, which values 1. The area after this equivalent process is global average biological productive area with the global average ecological productivity that can be summed. Ecological footprint can be expressed as:

$$EF = N \times r_i \times \sum_{i=1}^6 aa_i \quad (1)$$

EF is the total ecological footprint, N is region's population, r_i is equivalent factor, and aa_i is biological productive area per capita after equivalent process. What the ecological footprint finds is the demand for the

biological productive area used for production of all the resources consumed by people and absorption for all the wastes produced by people in a certain time and certain region.

Regional resources carrying capacity evaluates the supply of ecological footprint in target region which is the sum of all the biological productive lands, representing the supply ability of ecosystem's natural resources in this region. The great differences in productivity per unit area not only exist in different types of biological productive areas, but in the same type for different resource endowment all over the world when we calculate ecological carrying capacity. Such discrepancy can be expressed by yield factor which is the ratio between productivity of a certain type of land in a country or region and the global average productivity of the same kind of land, mainly reflecting the differences in land managing, technology and so on. The formula of ecological carrying capacity is:

$$EC = N \times ec = N \times \sum_{i=1}^6 a_i \times r_i \times y_i \quad (2)$$

EC represents the regional total ecological carrying capacity; N represents population, a_i implies biological area per capita, r_i is equivalent factor, and y_i is yield factor.

2.3 Ecological footprint's calculating steps

Calculating steps are: (1) shift the consumption of biological and energy resources into global average biological productive area with the global average ecological productivity that can be summed according to the subsidiary ledger of residents' consumption statistics; (2) analyze target region's land use status and area in the investigation period; (3) the demand part of ecological footprint multiplies equivalent factor, the supply part, namely region resource carrying capacity, multiplies equivalent and yield factor to shift into the per unit biological productive area that can be compared, and deduct 12% for biology diverse protection; (4) compare ecological footprint's demand and supply to gain the result, ecological surplus or ecological deficit.

3. CASE STUDY: ECOLOGICAL FOOTPRINT IN BEIJING'S 7 MOUNTAINOUS REGIONS.

The area of Beijing's mountainous regions amounts to 10072km³, or 62% of that of the whole city, mainly covering in western, northern, and eastern

part. 7 of all 18 counties, Fang Shan, Men Tougou, Chang Ping, Yan Qing, Huai Rou, Mi Yun, and Ping Gu, have more than 50% mountainous area up to 66.6%, 98.5%, 59.2%, 72%, 81.9%, 56.2%, and 57.2%, respectively. Beijing is one of the largest cities lacking water seriously in the world. Per capita water resource a year is less than 300m³, only a eighth of global average and a thirtieth of nationwide average. It is regarded as water resources shortage. Surface water systems and the main reservoir are locating in the mountainous areas of Beijing. It is recon that more than 80% of water supply comes from these areas. By the end of 2005, Beijing's permanent residents are 15.38million, 3.384million of which (about 22%) are in 7 mountainous counties, whose total rural population is 1.89million.

These counties are not only the first screen for ecological environment protection, but the water conservation and supply places. Meanwhile, for their profound cultural details, and outstanding tourism advantage, they are also the important tourist resorts, and manufacture and processing base for green food. Sustainable development there is favorable to windbreak and sand fixation, water conservation, and air purification in Beijing.

3.1 Ecological footprint calculation of 7 mountainous counties of Beijing in 2004 and 2005

Wine is added to the general food consumption in statistics and it can be shifted into the need for cultivated land for its self-producing features. By the end of 2004 and 2005, rural population of 7 counties was 1.815million and 1.89million. The results of ecological footprint's supply and demand in 7 counties of 2004 and 2005 are expressed in table 1 and 2 (data resources: National Bureau of Statistics in Beijing rural socio-economic survey team, Beijing Statistics, 2005; Beijing Statistics, 2006)

Table 1. Rural population's supply and need for ecological footprint in 7 counties, 2004

Demand for ecological footprint				Supply for ecological footprint			
Land type	Total area	Equivalent factor	Equivalent area	Land type	Total area	Yield factor	Equivalent area
	Ha/per capita		Ha/per capita		Ha/per capita		Ha/per capita
Cultivated land	0.2567	2.8	0.71876	Cultivated land	0.0633	1.66	0.2942
Forest land	—	1.1	0	Frost land	0.4033	0.91	0.4037
Gross land	0.1276	0.5	0.0638	Gross land	0.0011	0.19	0.0001
Building site	0.0026	2.8	0.00728	Building site	0.0747	1.66	0.3472
Waters	0.1411	0.2	0.02822	Waters	0.0304	1	0.0061
Fossil and energy	0.1033	1.1	0.14333	Co2 absorption	0	0	0
				Total supply area			1.0513
Total ecological footprint			0.9614	Biological diversity protection (12%)			0.1262
				Ecological protection area (18%)			0.1892
Ecological deficit (Ha/per capita)			0.2259	Total ecological carrying capacity			0.7359

Table 2. Rural population’s supply and need for ecological footprint in 7 counties, 2005

Land type	Demand for ecological footprint			Land type	Supply for ecological footprint		
	Total area	Equivalent factor	Equivalent area		Total area	Yield	Equivalent area
	Ha/per capita		Ha/per capita		Ha/per capita	factor	Ha/per capita
Cultivated land	0.2874	2.8	0.80472	Cultivated land	0.0604	1.66	0.2807
Forest land	—	1.1	0	Frost land	0.3876	0.91	0.388
Gross land	0.1554	0.5	0.0777	Gross land	0.0011	0.19	0.0001
Building site	0.0028	2.8	0.00784	Building site	0.0719	1.66	0.3422
Waters	0.1724	0.2	0.03448	Waters	0.0292	1	0.0058
Fossil and energy	0.1352	1.1	0.14872	Co2 absorption	0	0	0
Total ecological footprint			1.07346	Total supply area			1.0088
				Biological diversity protection (12%)			0.1211
				Ecological protection area (18%)			0.1816
Ecological deficit (Ha/per capita)			0.3674	Total ecological carrying capacity			0.7061

3.2 Analysis of results

From Table 1, we find in 7 mountainous regions, 2004, per capita ecological footprint, per capita ecological supply area, and per capita ecological deficit by 12% biodiversity deduction according to general method was 0.9614ha, 1.0513ha, 0.0363ha respectively; similarly, from Table 2, we find in 2005, they were 1.0735ha, 1.0088ha, and 0.1858ha. According to ‘Beijing Urban Overall Plan’, the guiding principle of mountainous sub-region is ‘it is the ecology screen for Beijing, rich in historical and cultural heritage and natural resources. Ecosystem maintaining, water protection, moderate tourism, and eco-agriculture exploitation comes priority. Strictly control the exploitation and construction in shallow mountains, as well as strengthen greening construction and ecology recovering’. Ecological service is mountainous area’s prime function.

We decide to add 18% of area for ecological environment protection, namely 30% of area deduction, so that its function can better satisfy the urban overall plan’s requirement. By adjusting, from Table 1, rural population’s per capita ecological deficit is 0.2259ha in 7 counties, 2004, 21.49% of total supply area, 30.70% of total ecological carrying capacity that year. From Table 2, rural population’s per capita ecological deficit is 0.3674ha in 7 counties, 2005, 36.42% of total supply area, and 52.03% of total ecological carrying capacity that year. To compare them, we find the larger ecological footprint, reduced total supply area, and growing rather than decreasing total rural population lead expanding ecological deficit.

Via calculating, we also find that the optimum population in 7 counties’ rural areas was about 1.389million, 0.426million smaller than the real one in 2004. In 2005, the optimum population was 1.243million, 0.647million less

than real population. In a word, 7 counties' population has greatly exceeded regional ecological carrying capacity that we have to conduct ecological migration to satisfy its function orientation and ecological screen role. Moreover, great promotion of rural living level and increase of rural population lead to different optimum population in two years.

In the research program 'Beijing's mountain land-use planning and comprehensive treatment' the researcher used ecological footprint method as well to conclude that under the production & technology and consumption condition in 2003, the population supporting capacity in mountainous areas is 1.02million. Considering its smaller cultivated land area-60927.8ha (the area here was the area of land adaptive for cultivating based on its land suitability evaluation), the optimum population in this research program was also smaller than what we have calculated. In conclusion, rural optimum population in 7 mountainous counties is about 1.2million.

4. COUNTERMEASURES AND DISCUSSIONS

4.1 Countermeasures

According to the results, per capita ecological footprint in tow years were deficits, along with upward trend. In 2003, per capita ecological footprint of China was 1.547ha, per capita deficit was 0.817ha (Min Chen, Lijun Zhang, Rusong Wang 2005); However, per capita ecological footprint was 1.8016 and per capita deficit was 1.2463ha in 2004 (Xiaoqing Zhong, Yongliang Zhao, Shan Zhong 2006). The existence of ecological deficit will inevitably undermine Beijing's capital functions of better play and 2008 'Green Olympics' perfect realization, though comparing to the whole country, the deficit was small. As a public good, a sound ecological environment can be offered only by government that we propose to seven-county ecological construction on its new building in rural places the primary position since it is not only related to the current livelihoods and long-term interests of rural people in these regions, but also to the major strategic issues such as realization of sustainable development and perfect performance of Beijing's capital function. We should insist on 'Scientific Concept of Development' to guide construction of mountainous countryside, and properly handle the relationship between ecological construction, along with the economic development, and peasants to increase income. Our proposals are as follows:

(1) Strictly control the growth of permanent residents in mountainous areas. Compensate people whose native places are in these regions but no longer live there with money to encourage them to emigrate. Speed up the

eco-emigration project, impose a strict ban on immigration in order to reduce the population growth, and decrease eco-pressure by appropriately restricting periodic immigration.

(2) Implement a series of key ecological projects. Encouraging residents to purchase from outside to reduce the local production. Via external import, changing their lands into forests to increase regional forest coverage and environmental capacity, which call for fiscal transfer payment, as well as a certain eco-compensation for mountainous residents, and establish an effective long-term mechanism.

(3) Strictly control the scales of land use, and establish a real-time monitoring system. Implement the area capping of housing.

(4) Try for resources optimization deployment under the advantageous trend of regional cooperation in Jingjin Ji region. Being a wide hinterland for Beijing and Tianjin, Hebei is the major ecological resources supplier, and they three are inseparable in the areas of ecological protection and water resources utilization. Beijing should try to incorporate closely with Hebei to strengthen the concerted mechanism of resources supply, water resources utilization, and ecological improvement in order to solve the potential problems during development. Hebei should make full use of this trend for welfare enhancing change within region under the premise of overall improvement.

4.2 Discussion

Ecological footprint does not take other human materials demands into account, though it well evaluates human consuming of biological resources and energy. When calculate ecological footprint in target region through ecological footprint method, we consider the consumption statistics account seriously. Despite 12% area deduction for biodiversity protection, we also introduced another 18% area deduction for ecological protection based on the expert evaluation so that the mountainous ecological function can be better practiced. As being a new attempt, there are inevitable many things need to be improved, though to some extent it is subjective.

Through this empirical research, the following factors will affect ecological footprint index calculation and evaluation results:

(1) The basic assumption of the model for ecological footprint analysis is that all the land types are exclusive. Because of this, land can be simplified as it only has a single function, and this simplification process makes land's diverse functions as well as to some extent functions of alternative ignored completely, which leads to a systematic error of less ecological footprint supply.

(2) As mentioned in this issue, the factors included in calculating model

are not enough. Particularly we should focus on main factors that limit target region's development so a better measurement of local eco-consumption and a more precise conclusion of local eco-consumption can be gained.

(3) With the rise of tourism and the existence of a large floating population, when we calculate the demand for the total ecological footprint, the final theoretic result will be inevitable lower than the actual if the population value used in our model only comes from statistical yearbook.

(4) Statistical data has directly determined the conclusions' accuracy and reliability.

To sum up, ecological footprint is a research method based on data of present situation which is used to evaluate human activities' effects on biosphere and its results have a certain practical guiding significance.

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DESIGN OF SIMULATION STRATEGY FOR CORN CLEANING ON DISCRETE ELEMENT METHOD

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Abstract: The past efforts made on the corn cleaning dynamics were reviewed. Based on Discrete Element Method model, a simulation method for corn cleaning dynamics was then proposed, composing the following design factors: 1. 2-D discrete model and its related factors; 2. parities and magnitude of computation, consideration of the two factors upon application; 3. test platform design. The implementation of this plan will illustrate the dynamics of corn cleaning, benefiting the efficiency of cleaning machine design and the improvement of production economies.

Keywords: Discrete element method (DEM), corn cleaning, strategy, simulation

1. INTRODUCTION

Cleaning is one important step of corn harvesting. The earliest record on cleaning dated back to the Spring and Autumn period in China, in which manual sieve and windmill were used. The modern combine harvesters applied both wind cleaning and sieve cleaning. And the repeated revision on the design work for the configuration and key parts have been made by agricultural engineers, with an aim of reducing energy demand.

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Dynamics of corn cleaning still remains as a complex problem. The mainstream efforts of research are still concerned with pneumatic – reciprocal sieve mechanism, and mostly are of parameterized characterizes, e.g., adjusting physical parameters of processed materials and changing construction and motion to illustrate its cleaning performances. The commonly used theory is particle dynamics, in which the whole grain collection is taken as a single particle. And trajectory tracing and high-speed photography have also been adopted to quantify the cleaned grain (Fang et al., 1999; Ge et al., 2001; Jianping et al., 1997; Wenqing et al., 2002; Wenqing et al., 2001) . In the cleaning procedure, grain behaves much like that of a fluid, and thus a precise description of its state is a primary problem.

DEM was proposed by Cundal in 1970's (PA et al., 1979) , which fundamental concept was to take the discrete grains as a collection of particles with particular shape and mass. And contacting mechanics model was assigned to the neighboring surfaces between particles and boundaries or between particle and particles. Wang introduced DEM into China and quickly used this theory in soil mechanics (Yongjia et al., 1991; Jibo et al., 1990) . And Thornton DEM was applied by China agricultural university in 1998 for simulation (Yong et al., 1999) .

Flowing is a typical property of grain as it is transferred to platy shaking sieve in cleaning. The grain collection is not a continuum substance, and force interaction exists among grain particles. Thus taking grain collection as a whole will introduce error for simulation, making it impossible for a correct interpretation of interactions among particles. Compared with this, DEM is much better. Sakaguchi and Suzuki et al. investigated the vibration cleaning process of paddy and rice with DEM (E et al., 2001) . Introduced a 2-D plate model with relative parameters, A DEM simulation strategy was supplied and then implemented.

2. THE BASIC IDEAS OF SIMULATION ON DEM

The basic idea of DEM simulation on grain cleaning provided in this paper is to apply a micro-mechanics method, i.e. study on particle-particle and particle-boundary interactions. By providing correct contacting mechanics model and supplying governing equations, calculation with rational algorithms is performed on work station to provide dynamic parameters such as force, displacement, deformation and velocity. The on-time simulation serves as a complementary method for scientific design on cleaning mechanisms, for innovative theory, calculation and assessment, which main principles include (Yong et al., 2003):

1) Grain particle was taken as a 2-D platy element. To achieve a precise simulation, soybean was used in experiment to illustrate layering and sieving

performances of grain on platy sieve. Sieve surface was simplified as a plane, and sieve openings were simplified as virtual boundary. When the contacting width between grain particle and virtual boundary reaches $2R$, the grain will pass the sieve.

2) Visco-elastic model was used for grain interaction modeling to analyze normal and tangential contacting force. The amount of normal overlaying is the difference between radius and center-to-center distance, otherwise it is regarded non-contacting.

3) Central differential method was applied with small time elapse to calculate kinetic differential equations, giving the displacement and velocity of each particle in each instant.

4) DEM simulation was then conducted with reference to displacement and velocity table of particle collection.

5) Result was laboratory tested with high-speed camera recording and compared with simulation. By adjusting experimental parameters a satisfactory result was achieved.

3. DESIGN OF SIMULATION PROGRAM FOR GRAIN CLEANING

3.1 Discrete element model of grain in cleaning

Analytical model should be constructed before DEM simulation. In addition to the requirement of the geometrical approximation of the model grain to that of the real one, factors must be considered for the judgment of the contacting condition between neighboring particles or particle and boundaries, and for the simplicities of the calculation of the overlaying magnitude, so that the computing capacity of the computer is satisfied and certain precision of calculation is balanced.

Based on the mechanics and contacting mode of discrete materials, the underlining models are listed in table 1

Table 1. Analysis of the various particles of the main features of model

Types of particles	Physical characteristic	Contact judgment	Computation	Applicability
ball-particle	better	easy	relatively less	sand, soybean etc.
ellipsoid -particle	excellent	complex	heavy	rice etc.
ball-column	excellent	difficult	heavy	some soil particles etc.
hypersphere model	excellent	difficult	heavy	complicated grains etc.
combination ball model	good	difficult	heavy	nail grains etc.

Considering laboratory test and theoretical research, 2-D platy model of particle were applied, which is illustrated in fig. 1.

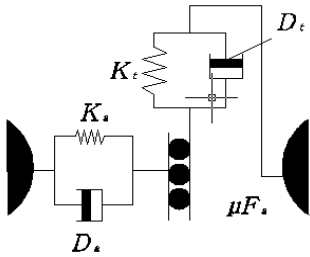


Fig.1: Contact model between particles

Fundamental parameters in the applying model were measured and provided in table 2.

Table.2 The main physical parameters

1000-grain weight	Friction coefficient	Contact stiffness (particle –particle)	Contact stiffness (particle–border)	Damping coefficient	Recovery coefficient
49. 5(g)	0.402(N/s)	25000 (N/s)	45000(N/s)	0.2(Ns/m)	0.7

Elasto-damp-friction model was applied on the contacting between particle and sieve (Asmar, 2002; Anyuan et al., 2002) , which is shown in fig.2.

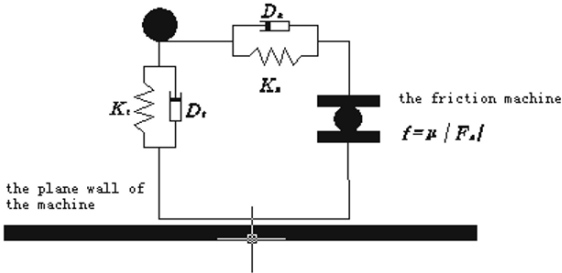


Fig.2 :contact model between particle and sieve plate

One assumption of the model is the point contact between ball particle and sieve surface, allowing certain amount of overlaying in colliding. Contacting force is determined by both the magnitude of overlaying and the relative velocity of the two.

Contacting force is generally considered as the addition of elastic force and damping force, which are calculated in the following equations (Hongguan et al., 2006) :

$$F_c=k*\delta \tag{1}$$

$$F_d = D * V \quad (2)$$

Thereinto, K is the contact stiffness between particles and the wall of container, δ the composite quantity between them, V the relative velocity for the particles and the wall at the contact points, and D the damping coefficient between them, D is computed according the following formulas:

$$D = 2\gamma \sqrt{m_{ps} * k} \quad (3)$$

$$\gamma = -\frac{\ln(e)}{\sqrt{\pi^2 + \ln^2(e)}} \quad (4)$$

$$m_{ps} = \frac{m_p \cdot m_s}{m_p + m_s} \quad (5)$$

Thereinto, e is the recovery factor for the collision between particles and the plane, m_p is the quality of the particle, and m_s is the quality of sieve surface. Divide the contact force into normal and tangential contacting force in the actual calculation, and compute respectively in the form of incremental direction.

3.2 Consideration of simulation accuracy

It is not easy to simulate the grain cleaning with DEM. In order to reach a certain simulate accuracy, scientific and careful consideration is indispensable. The current level both at home and abroad only rest on the reasonable characterization and tending to be similar. When simulating with DEM, we seize the main factors so that simulation is right in the shape firstly and then explore in depth to make the simulation accurate in essence. The important questions we have to consider are as following:

1) The equivalent of particle (Yong et al., 2003)

The analysis and simulation of the grain cleaning need to study corresponding relationship between particles and the model. We can get the rational parameters of the model according to the physical properties of particles practically. The main considerations dealt with equivalent in this study are:

(1) The principle of equal quality

In the calculation area, the total quality of grain should be equal to the particle groups in the model, and at the same time, the total quality of grain should be equal to the particle groups when they are equal in the volume, that is they have the same density, so in this way the mechanical responding concerned to the gravity can be assured in the mass.

(2) The principle of equivalent fluidity for particles

With the actual grain geometry model having a great gap with the ball-model, the stream of grain in the sieve surface also is varies with the fluidity of the model, so it is need to modify the parameters of that model in order to make the model close to reality as far as possible. We should adjust the particle-friction coefficient and adhesion surface energy so that the ball-model and the corresponding tests have the same rest angles, which is the typical index indicating the friction property and fluidity of discrete material.

2) Calculating scale

Because the computation load will increase in the way of geometric series when increasing the number of particles, so a very high capability for computer is demanded. At the same time, the effect of simulation will decrease sharply if the number of particles reduces. Therefore, we choose a relatively rapid one after studying much arithmetic and recur to the advanced computing platforms and graphical interface, so that a better simulation outcome can be gained.

3.3 The simulation process with DEM

With the DEM and programming tools, the analysis program of DEM can be written out. The flow chart of programme is as follows:

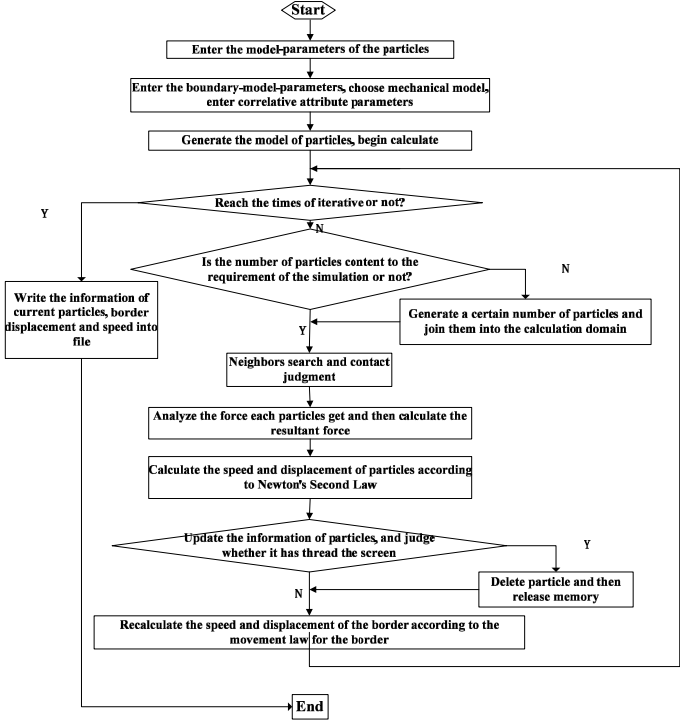


Fig.3: flow chart based on DEM

3.4 Test verification

The simulation of the corn cleaning is needed to be verified .Test verification is mainly as follows:

1) Measure the physical characteristics of grain

In order to make the particle model and the actual equivalent similar as far as possible, the physical characteristics of grain muse be measured such as the 1000-grain weight, friction coefficient, contact stiffness (particle – particle and particle–border) , the recovery coefficient and the rest angles etc.

2) Verify the simulation results in the test platform

Whether the simulation graphics based on DEM is vivid of not, the results will be verified by the experiment in the test platform . According to the configuration of combine ,we have designed the general experimental systems, which is composed of plane vibration system and high-speed motion analysis system(shown in Figure 4). In it,

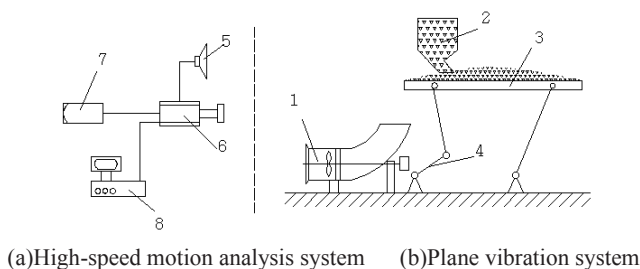


Fig.4: The experimental systems

1-fan 2-feeding device 3-vibration sieve 4- motor 5- high-power light source 6- high-speed camera 7- mobile HD 8-computer

It is designed specially for studying the trajectory of materials. The device mainly includes gantry, wobbling boards, screen, fan, motor, inverter and sampling box.

In the device, the length of the cleaning sieve is 1000mm, width 300 mm, and they can be changed when flat board or through sieve is needed. The sieve works in the form of linear reciprocating vibration driven by Crank Linkage.

The centrifugal fan is used. Type: YDF - 2.24B-6S; Standard rated speed: 960 r/min ; Flux: 1300 m^3/h . Adjust the speed of fan, the speed of air current can be changed.

Y-type alternating current stepper motor is selected. It's rated voltage is 220 V , rated power 0.75 KW , and rated speed 1440 r/min . The speed of driven motor should be adjusted according to the need of requirements.

The inverter is called as BT40D digital transducer.

The two sides of the cleaning room are made respectively of organic glass and white cardboard. The adoption of organic glass is for the sake of visualization research. The vidicon can record the motive scene through the organic glass. Using the white cardboard is in favor of enhancing the contrast of backgrounds and objectives and is conducive to the following image processing.

The MVC1000SAGE30 high-speed camera produced by Microview Company is used in this test.

4. CONCLUSIONS

Because the grain groups own the characteristics of multiphase, dispersing, kinetic and randomness and so on in the cleaning process, its complicated kinetic and mechanical specialties bring a great obstacle to the improvement and innovation of harvest machines. Based on the research outcomes of predecessors and combined the properties of corn sieve, the simulation strategy for corn cleaning on DEM is carried out, This project is implementing in our laboratory.

The simulation strategy is also applicable to other analysis of discrete element. Combining the DEM and the configuration of grain cleaning and then simulating in computer, the design efficiency for the grain cleaning machine and economy of the products can be improved greatly.

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DECISION SUPPORT SYSTEM BY (ORDERED WEIGHT AVERAGING) OWA METHOD

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Abstract: Nowadays, using the technology and computers for decision making in a particular field is one of the subjects which in the level of making decisions and industrial managements has been very much noticed. Especially, the decision which on the base of current specific condition is required, such as making decisions in the selection of suitable primary tillage equipment for given conditions of a farm.

Tillage consumes much more energy among all the other agriculture operation, so one mistake in optimum selection of tillage implements, not only wastes the huge amount of energy, but also it leads to serious impacts on soil, crop and other farm operation. The optimum selection of tillage implement is affected by environmental and geometrical conditions and factors and available facilities.

In this paper an attempt has been made to use the data fusion theory (Ordered Weight Averaging, OWA) to combine important factors to make a decision and to suggest a classified list of implements that can be used for primary tillage. By comparing the results obtained from the software and experts' suggestions it can be found that the software is compatible with scientific references by 99%, whereas experts' suggestions are compatible with scientific references only 94%.

Keywords: Tillage implements, Data fusion theory, Ordered weighted Averaging, Fuzzy rules, Decision support systems

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1. INTRODUCTION

In farming age, human, came to know the land, plants and environment in order to provide his exigencies and food needs, endeavoring to get the most with the least input Nowadays, human has realized the importance of soil and other resources and has always tried to hold them long-lived.

Agricultural mechanization is a symbol of fusion between agriculture and industry. Today, terms of power and hardware has vanished and human asks for information and software instead; the storage and process of benefiting information plays an important role in many scientific fields such as *Information Technology*. (Sharifnasab H., et al, 2001)

The tillage which consists of different physical operations on the top or deep soil is aimed to prepare an appropriate seedbed for cultivation. Not considering this decisive operation causes loss of energy, and moreover contributes consequent disadvantages. By now, more than 150 implements with different configurations have been designed and manufactured for tillage operations in the field. They are expected to become even more complicated and variant by considering the need for integration of cultivation steps. Experts now believe that tillage must be performed in two different levels; one in deep soil and with more power, called “*primary tillage*” and the other on the top soil and slighter accordingly named “*secondary tillage*” (Shafii A., 1995).

In this paper, the *data fusion* theory was employed by using the technique of *Ordered Weighted Averaging* (namely called OWA operator) to develop software named *Decision Support System* (DSS) for defining all implements of different types. With regard to the environmental conditions, selection is made in order to choose the optimum primary tillage implement. This selection is based on the calculation made according to the values given to each implements so that, the best ones is offered to the user.

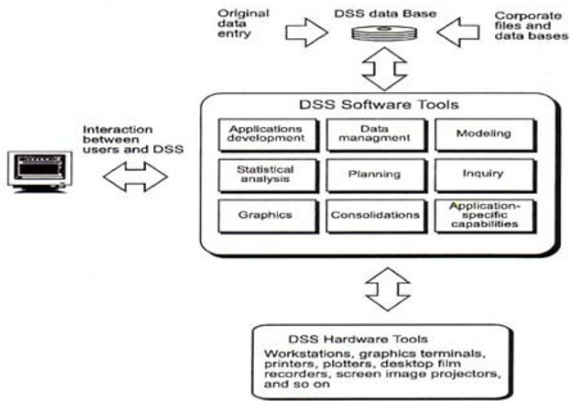


Figure 1-The DSS components (Sarafizade A., A. Alipanahi, 1384)

The significant feature of OWA operator is its great flexibility and simplicity to the user. The OWA operator has many applications, i.e. in decision making, expert systems, fuzzy control, database systems, image compression, etc. Numerous applications in various field, prove the OWA operator to be efficient and functional [(Cutllo V., J. Montero, 1994),(Engelmann K.J., et al,1992),(Kacprzyk J., 1990),(Yager R. R., 1992),(Yager R. R., D.P. Filev,1992),(Yager R.R., 1991)].

2. MATERIAL AND METHODS:

Tillage and related implements

Considering the two steps and numerous implements associated with tillage, this operation consumes the most energy. As shown in Table 1, priority of implement is ordered with the following fuzzy labels; Excellent, Good, Usable and Not Usable.

The goal of the DSS software is to search based on the defined conditions (by user) and to arrange the searched implements respectively, then it presents a ranked list to answer to the user.

Table 1- Fuzzy relation between the conditions and tillage implement (Sharifnasab H., 2001)

Category	Conditions	Implement type	Fuzzy label
Land Dimension	Wide land	Towed	Excellent
		Semi-mounted	Good
		Mounted	Usable
	Medium land	Semi-mounted	Excellent
		Mounted	Good
		Towed	Usable
	Small land	Mounted	Excellent
		Semi-mounted	Not Usable
		Towed	Not Usable
Geometric Shape	Equal land	Reversed One way	Excellent Good
...	Unequal land	...	...

Table 2- Classification method in the DSS data base (Sharifnasab H., 2001)

Code set	Code details	Application
A	1	Primary tillage equipment
	1	Moldboard plows
B	2	Disk plows
	3	Chisel plows
	4	Subsoilers
	5	Rotary tillers
C	1	Mounted
	2	Semi-mounted
	3	Towed
	3	Towed

The advantage of this method is that it allows the user to select other alternative if the introduced implement with superior abilities fails to help for any reason. The point is that some concepts indeed do not exactly signify

to illustrate the situation. For example, if we define a 50 ha field as big, then a 49 ha field will not be regarded as big, whereas there is no significant difference between 49 ha and 50 ha to choose the tillage implement. Applying fuzzy concepts and take advantage of fuzzy labels, such as big, medium, small and etc, we can solve many problems.

Example: For defining an implement such as a mounted - one way moldboard plow with cylindrical moldboard and stubble bottom with simple shared equipped with adjustable landside, we can write:

A(1)-B(1)-C(1)-D(1)-E(1)-F(1)-G(1)-H(2)-I(0)-J(0)-K(0)-L(0)-M(0)-N(0)-O(0)-P(0)-Q(0) (1)

If we assume that all probabilities for providing the implements are existed, then the total number of implements, in which the software can list, will be equal to:

No. Of Implements = N_A * N_B * N_C * N_D * N_E * N_F * N_G * N_H * N_I * N_G * N_K * N_L * N_M * N_N * N_O * N_P * N_Q (2)

Total = 161740800 (3)

In which N_A presents the number of sub - tools in the category A. As shown in table 3, some aspects are influenced by more than one factors (i.e. selecting of plow or bottom types), so considering only a single factor won't be accountable. Therefore, to account for all conditions in choosing an implement, we must employ a method in which all factors and priorities among the conditions should be explained with considering the influenced coefficient. For instance to choose a bottom, according to table 3, it's obvious that factors like: soil class, forward speed and plowing depth are influencing whereas we still don't know the priority of their influence and/or we can not assume their influence, alike.

Table 3- A survey of interrelation between the Influencing and Influenced aspects (Sharifnasab H. , 2001)

No	Influencing aspects	Influenced aspects	Codes
1	Land dimensions	Connection type	C
2	Land geometric shape	Implement orientation	D
3	Soil class	Bottom-moldboard-share-disk	E-F-G-L
4	Fertilizer existence	Plow type	B
5	Forward speed	Bottom	E
6	Soil humidity	Plow type	B
7	Land slope	Moldboard	F
8	Hard pan existence	Plow type	B
9	Plowing depth	Bottom	E
10	Plowing time	Plow type – share	B-G
11	Land use	Plow type – disk plow type	B-K

Information Technology in Management and Decision Making
Decision Support Systems (DSS) were contrived in the late 1970s and early 1980s considering the necessity for the systems to be able to assist organizations in trouble with analysis and proposing different solutions. These systems are commonly interactive and mostly designed for

administrators. A DSS solves a particular problem which might be occasional and not routine. Supervisors can compensate information shortcoming with DSS and raise their decision's quality consequently. The main abilities of the DSSes are an applied program-providing tool, a data-managing tool, modeling, statistical analysis method, planning, inquiries and data fusion (Sarafizade A., A. Alipanahi, 2005).

Ordered Weight Averaging operator and its role in data Fusion

One of the important issues in decision making is integrating standards and forming the decision function (Azar A., H. Faraji , 2002). Sometimes we require all the standards to be accomplished and sometimes we may intend to fulfill at least one standard. These two requirements depend on "and" and "or" operators for standard functions fusion. The OWA operator performs a sort of collection which stands amid the mentioned cases; that's why it is called "orand" operator. It was first introduced by Yager, however new versions of this operator have been proposed by him to other researchers. An OWA operator with n dimensions is a $F: R^n \rightarrow R$ mapping, with an n-dependent vector $W = [w_1, w_2, w_3, \dots, w_n]$ with the condition

$$\begin{cases} w_j \in [0,1] \\ \sum_j w_j = 1 \end{cases}$$

so that:

$$F(a_1, \dots, a_n) = \sum_{j=1}^n w_j b_j \quad (4)$$

in which a_i is a factor for weight calculation (importance) and b_j is the j_{th} great factor among a_j s (Yager R. R., 1992).

The basic fact about this operator is that a weight like w_j is not relevant to a particular argument a_i , but relates to a collocated place. This collocation method indeed, makes this operator to behave non-linear. If B is a vector with n members signed as b_j s, then OWA operator will be as follows (Kavoosi K., 2001).

$$F(a_1, \dots, a_n) = W^T B \quad (5)$$

3. RESULTS AND DISCUSSION

Results:

The most important task is to conduct the problem conditions based on Yager theorem for calculations associated with OWA operator.

Fuzzy rules allow us to find a proper "Regular Increasing Monotone"¹ (RIM)

function to compute OWA weights. This method uses a RIM function such as "quantifier" to calculate the weights:

$$Q(r) = Q_a(r) \quad (a \geq 0) \quad (6)$$

Thus:

$$w_j = Q\left(\frac{j}{T}\right) - Q\left(\frac{j-1}{T}\right) \quad ; \quad j=1,2,\dots,T \quad (7)$$

Where T is the number of weights and it's obvious that:

$$\sum_{j=1}^T w_j = 1 \quad (8)$$

But it's important how to choose " a " and $Q_a(r)$ function. A proper way to choose a is constituting several fuzzy rules which determine the range of weights, then value of a will be achieved concerning the function definition (Yager R.R.,2001). Each question results in a specific weight, after modeling the answers of user [answers to user/questions of user], naturally different from another questions weight. The figure 2 illustrates the idea.

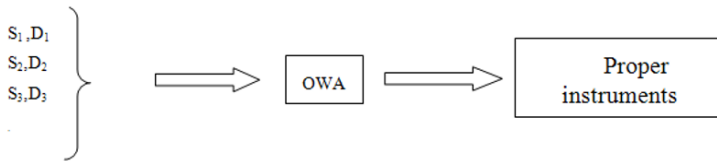


Figure 2- application of OWA on the User's data

In which, s is the data's value and D shows the data.

Obviously:

$D \in \{ \text{field dimensions, geometric shape, soil class, fertilizer existence, Moving speed, humidity, land slope, plowing deepness, ...} \}$ (9)

$$0 \leq S_i \leq 1 \quad \text{and} \quad \sum_{i=0}^n S_i = 1 \quad (10)$$

The resultant optimum instrument will be formulated as follows:

$$(S_a A_{ia}) (S_b B_{ib}) (S_c C_{ic}) (S_d D_{id}) (S_e E_{ie}) (S_f F_{if}) (S_g G_{ig}) (S_h H_{ih}) (S_i I_{ii}) (S_j J_{ij}) (S_k K_{ik}) \dots \quad (11)$$

In which:

$$\begin{aligned} 0 &\leq i_a \leq N_A \\ 0 &\leq i_b \leq N_B \\ 0 &\leq i_c \leq N_C \\ &\vdots \\ 0 &\leq i_q \leq N_Q \end{aligned} \quad (12)$$

s values are determined according to the data bank and defined conditions by the user. So we have:

$$S \in \{ \text{excellent, good, usable, not usable} \} \quad (13)$$

The following amounts have been equaled to quantify the above fuzzy labels:

$$\begin{aligned}
S(\text{excellent}) &= 1 \\
S(\text{good}) &= 0.66 \\
S(\text{usable}) &= 0.33 \\
S(\text{not usable}) &= 0
\end{aligned} \tag{14}$$

In order to achieve each point's weight in OWA formula, we must choose an appropriate quantifier. "Yager" believes that the following quantifier is not mathematically complicated, and also makes approximately true answers. So, we define it as follows (Moghadas A., 1998):

$$Q(r) = r^a \quad (a \geq 0) \tag{15}$$

Now, to calculate the weights (w), we have:

$$w_j = Q\left(\frac{j}{T}\right) - Q\left(\frac{j-1}{T}\right) \tag{16}$$

in which T is the total number of weights (the total number of maximum components in an instrument; currently A to Q: 11) the above equation also includes the condition: $\sum_{i=1}^T w_i = 1$

w_1 is the highest point's weight, w_2 is the next point's weight, ..., and w_{17} is the least point's weight in defined conditions by user. To calculate the best instrument and most fitting answers, we need to calculate the optimum a.

We'd better design and accomplish experiments to determine the importance of a properly beside other characteristics; For example, an experiment to show whether the land slope or humidity is more important to select a tillage instruments.

$$\text{We'll obviously need } \frac{n^2 - n}{2} = \frac{11^2 - 11}{2} = 55 \text{ experiments (currently)}$$

(Asgharpoor M.J., 1998); in which n is the number of different environmental conditions effective on choice, such as: land dimensions, geometric shape, soil class, etc. After performing the experiments, once again we can take advantage of OWA method by substituting the result values.

Presently, we need two border rules to limit upper and lower values of a.

The first rule:

If more than m percent of sub-tools in a tool, have a point more than y, the ultimate point must be greater than x.

The second rule:

If more than m percent of sub-tools in a tool, have a point less than y, the ultimate point must be smaller than x. Considering these two rules, the upper boundary edge of a will be as follows:

upper boundary edge :

$$\begin{aligned}
w_1 &= (1/T)^a - (0/T)^a \\
w_2 &= (2/T)^a - (1/T)^a \\
w_3 &= (3/T)^a - (2/T)^a
\end{aligned} \tag{17}$$

$$w_j = (j/T)^a - ((j-1)/T)^a$$
 finally, adding up the weights will give:

$$\sum_{i=1}^j w_i = (j/T)^a \tag{18}$$
 in which:

$$j = \text{round up} [(m/100) * T] \tag{19}$$
 Referring to the first rule, we can model the equations as:

$$(j/T)^a * Y \geq x \tag{20}$$
 and this gives us :

$$a \leq \ln(x/y) / \ln(j/T) \tag{21}$$
 Similarly, to determine the lower boundary edge and considering the 2nd rule, we'll have:
 lower boundary edge:

$$(w_1 + w_2 + \dots + w_{T-j'}) * 1 + (w_{T-j'+1} + w_{T-j'+2} + \dots + w_{T-1} + w_T) * y' \leq x$$
 It is similar to formula (19):

$$j' = \text{round up} [(m'/100) * T] \tag{22}$$
 So, substitution will result:

$$[(T-j')/T]^a * 1 + [1 - (T-j')/T] * y' \leq x' \tag{23}$$
 and, consequently:

$$a \geq [\ln(x'-y')/(1-y')] / [\ln(T-j')/(T)] \tag{24}$$
 So, ultimately (Yager R.R., 1991):

$$[\ln(x/y) / \ln(j/T)] \geq a \geq [\ln[(x'-y')/(1-y')] / [\ln(T-j')/T]] \tag{25}$$

4. DISCUSSION

You have read *a* wide preview in appointing these two conditions (upper & lower boundary edges) and every expert defines these conditions based on his experience and interest. In table 5 are several scenarios to determine the boundaries (Sharifnasab H., et al, 2001).

Table 5-Some different scenarios about the first condition

<i>a</i>	<i>x</i>	<i>y</i>	<i>m</i>
1.17	0.6	1	60
1.02	0.7	1	70

Table 6-Some different scenarios about the second condition

<i>a</i>	<i>x'</i>	<i>y'</i>	<i>m'</i>
0.99	0.45	0.33	80
1	0.72	0.66	80

The explanation of table 5 and 6 are as follows:
The first rule:

* If more than 60 percent of sub-tools are excellent, the ultimate value of that tool must be greater than 0.6 .

* If more than 70 percent of sub-tools are excellent, the ultimate value of that tool must be greater than 0.7 .

The second rule:

* If more than 80 percent of sub-tools are usable, the ultimate value of that tool must be greater than 0.45 .

* If more than 80 percent of sub-tools are good, the ultimate value of that tool must be greater than 0.72 .

Now, if we assign an upper and a lower rule for *a*, we'll be able to achieve a limit for *a*:

$$0.99 \leq a \leq 1.17 \tag{26}$$

The above unequal results in: $a = 1$

even considering the second scenario, we'll have :

$$1 \leq a \leq 1.02 \tag{27}$$

From which $a = 1$ seems to be logical.

Noticing the calculated values for *a*, we accept (Sharifnasab H., et al, 2001): $a = 1$

Now, substituting $a = 1$ in weight calculation equations, gives us uniform weight. Approximation of *a* with 1 shows that there is no superiority between factors and conditions (i.e. field area, land slope, humidity, etc.) and it means that there is no definite answer to the question “*which factor is more important to choose tillage implement, field area or Filed slope; and how much?*” until the complete experiments are accomplished. Currently, the only solution is to assume that the importance of all factors are equal (Sharifnasab H., et al, 2001).

The following results are achieved from a statistical analysis with "*chi-square*" method and using "*SPSS*" software.

Here is the analysis of the results:

* The software's answers, correspond with the reference with a (1-0.011)= 99% probability (Table 8).

Table 8-comparison of soft ware answers with reference Statistical trial

Soft ware	
Chi. Square	6.400
.df	1
Asymp. Sig.	0.011

* The expert's answers correspond with the reference with a (1-0.058)= 94% probability (Table 9).

Table 9-comparison of expert's answers with reference Statistical trial

Soft ware	
Chi. Square	3.600
.df	1
Asymp. Sig.	0.058

* The software's answers correspond with the expert's answers with a $(1-0.058)=94\%$ probability (table 10).

Table 10-comparison of software answers with experts Statistical tria

	Soft ware
Chi. Square	3.600
.df	1
Asymp. Sig.	0.058

Considering the results, the reference is more in agreement with the software performance than the experts.

5. CONCLUSION

Applying the expert system software for choosing a tillage implement, not only decreases consultative costs, but also provides the option of reporting and well-timed consultation. The results of comparing software's answers with expert's answers, indicate that the software provides better answers (closer to reference).

As illustrated in the article, coefficient "a" (based on which OWA weights are defined) was achieved greatly close to 1, because of lack of adequate information about conditions effecting on proper implement selection. It is evident that if enough experiments are accomplished to determine the parameter's priorities, then weights (w) will be calculated more accurately.

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PRSRW: AN EXPERT SYSTEM FOR POSTULATING AND INFERRING RESISTANCE GENES TO WHEAT STRIPE RUST

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Abstract: Postulating and inferring resistance genes to wheat stripe rust are a complicated process and need abundant expertise. An expert system for postulating and inferring resistance genes to wheat stripe rust (PRSRW) was developed by China Agricultural University. The process of PRSRW was described on the basis of the user's requirement. The system structure and its main components were introduced, including database, inference process and user interface. Some issues regarding knowledge acquisition and representation of the expert system were concerned. A mount of experimental results showed this system was feasible and effective. At last, a conclusion was summarized.

Keyword: expert system; resistance genes; wheat stripe rust; knowledge acquisition and representation

1. INTRODUCTION

Wheat stripe rust caused by *Puccinia striiformis* f. sp. *tritici*, is the most destructive disease of wheat in China. In terms of area affected by stripe rust, China is the largest epidemic region in the world (Stubbs 1988). Stripe rust is the most destructive to autumn-sown wheat in northwest and southwest China when susceptible cultivars are grown and the weather is favorable for

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the disease (Wan et al. 2004). The epidemics of 1950, 1964, 1990 and 2002 in China caused yield losses up to 6.0, 3.0, 1.8, and 1.3 million tons (Li & Zeng 2002; Wan et al. 2004). The wheat's resistance to stripe rust mainly depends on the resistance genes. The use of resistant cultivars is the most economical and environmentally sound method to reduce damage caused by stripe rust. Gene postulation and inference helps to undertake a quick identification of the probable stripe rust resistance genes.

Gene postulation and inference is a complex and time-consuming process in gene analysis activities. It contains three important steps: resistance spectrum comparison, pedigree analysis, and integral information analysis. Resistance spectrum comparison not only consumes time, but often operates errors. It is difficult to make the conclusion of the probable resistance genes which the wheat cultivar contains, due to the shortage of pedigree information and integral information of the wheat cultivar. Thus, the system of a postulating and inferring gene developing becomes an urgent issue.

Computer application, which is revolutionizing information technology, is developing so rapidly that it is creating a huge opportunity for developing large scale application system. Expert system is an intelligent system which can treat a certain problem of a special area as an expert do by emulating human thinking.

PRSRW is an Expert System for postulating and inferring resistance genes to wheat stripe rust. It is supported by NSFC (National Nature Science Foundation of China). This intelligent system can simulate human wheat expert and postulate resistance genes to wheat stripe rust with a user-friendly interface. PRSRW contains a large amount of wheat information, which is needed to postulating and inferring resistance genes to wheat strip rust.

In this paper, we described the PRSRW. This paper was organized as follows: In Section 2 we described the domain background; Section 3 emphasized the knowledge acquisition and representation of PRSRW; Section 4 showed the system architecture and development; Section 5 described the implementation of PRSRW; then Section 6 discussed and drew some conclusions.

2. DOMAIN BACKGROUND

There are five steps involved in postulating and inferring resistance genes to wheat stripe rust as general practice:

(1) Experiment. The aim of this step is to obtain the resistance spectrum. The method is using wheat cultivars inoculated with selected different isolates of *Puccinia striiformis*, and obtain the resistance spectrum. The resistance spectrum was the elementary information for the further postulating.

(2) Comparison of resistance spectrum. This step is crucial in gene postulation which includes resistance spectrum comparison and analysis. Expert would compare the resistance spectrum between the detected wheat cultivars and the known ones, and then derive the probable genes in the detected wheat cultivars.

According to the results of step (1) and step (2), it is easier to estimate the possible resistance genes. However, this possibility should be validated by more expertise. It is necessary to carry out the further steps which involve analyzing the wheat's pedigree and integral information, such as time, space, etc.

(3) Pedigree analysis. A pedigree is a diagram of family relationships that uses symbols to represent genetic relationships. Using genetic principles, the information presented in a pedigree can be analyzed to determine whether a given gene is inherited or not and what the pattern of inheritance is. The experts would analyze genes that the ancestors contain. If the ancestors contain the gene which wheat cultivars had been examined out from wheat cultivars, it should be ascertained that the wheat cultivar contains, otherwise go to step 4 to check the Integral information.

(4) Integral information analysis. It is an assistant part of the pedigree analysis. Information in terms of time and space should be considered as the fundamental data in gene analysis. Integral information analysis refers to the process of detailed research, such as when the wheat comes into china and where the original wheat comes from.

(5) Decision making. Normally, the first two steps may identify the possible resistance genes of the wheat and the latter two steps shall further confirm this result. By precise experiment and postulating exactly, a conclusion can be reached.

Before developing an expert system of postulating and inferring resistance genes to wheat stripe rust, it is important to process a detailed analysis of domain problems. Methods and functions should be considered on how to simulate the intellective process of the domain expert and how to cope with the problems in computer system.

3. KNOWLEDGE ACQUISITION AND REPRESENTATION

3.1 Knowledge acquisition

Knowledge acquisition plays an important role in the expert system. Many knowledge acquisition tools had been developed for transferring expert knowledge into knowledge base. Knowledge acquisition is a difficult and time-consuming process which is commonly recognized as a bottleneck in the development of an expert system (Hayes-Roth et al., 1983). In this study, we used a multiple knowledge acquisition approach: human experts interviewing, machine learning and knowledge acquisition system.

(1) Human experts interviewing. Knowledge engineers get domain knowledge from human experts directly. Then transform the knowledge into the computerized representation forms. This is a time-consuming job because of the gap between the Knowledge engineers and Knowledge experts. It is also very difficult to elicit and integrate knowledge from multiple experts (Chu & Hwang, 2007). Knowledge engineers should cope with these problems carefully and make the knowledge base clearly.

(2) Machine learning. The machine learning approaches could learn the useful static knowledge of well-known objects by collecting many useful cases and instances with/without the involvement of domain experts (Lin et al, 2008). Neural network approach was used to train parts of the data information which were fuzzy and not clear. Then some useful results were acquired.

(3) Knowledge acquisition system. A knowledge acquisition system had been developed to help the human experts and knowledge engineers input the facts and the rules. The interface could collect data about the resistance spectrum of the wheat, pedigree and also its time and space information. This knowledge acquisition system can only be used by experts who had the authority. It also could facilitate experts to input, modify, delete and search facts and rules.

3.2 Knowledge representation

The main job of knowledge representation was translating the knowledge acquired from human expert into the system knowledge base. The translation of acquired knowledge into a system usable representation represents a roadblock to knowledge-based system (KBS) development (Walczak, 1998). Object-orientation provides several solutions to persistent knowledge

acquisition and knowledge representation problems including transportability, knowledge reuse, and knowledge growth (Walczak, 1998).

The object-orientation method was adopted as the formation of the knowledge representation in PRSRW. The core of the Object-orientation method is class. Three main classes were defined in the expert system. The separation of knowledge from representation structure combined with class enabled the system to present knowledge models to experts and users in any flexible format. It was also convenient for engineer to develop the system.

4. SYSTEM ARCHITECTURE AND DEVELOPMENT

PRSRW was consisted of six main components: database, knowledge base, integral database, knowledge acquisition subsystem, inferring engine and user interface. The structure was showed in Fig.1.

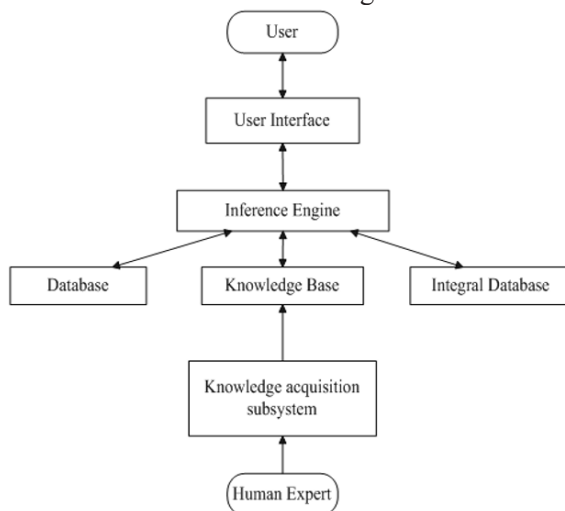


Fig.1: Structure of PRSRW

4.1 Development software and tools

The system used Visual Studio .NET as development tools, selected C# programming language as the development software and chose SQL language to index the database. Visual Studio .NET has the following characteristics: it is a Microsoft’s integrated development environment for creating, documenting, running and debugging programs written in a variety

of .NET programming language. Visual Studio.Net is a powerful and sophisticated tool for creating business-critical and mission-critical applications. The C# programming language is designed specifically for the .NET platform. It is a fully object-oriented, visual programming language. A programmer can create, run and test programs conveniently.

Database is the central and fundamental component of the expert system. It is responsible for storing all the data information used for the gene postulating and inferring in PRSRW. The computation results were then stored back in the database and displayed to user through user interface. This database was designed with SQL Server 2000.

The Database included a wheat information table, a gene information table, a pedigree database, an image table and a result table. These tables contained information of wheat's name, wheat's gene, wheat's pedigree, etc. The image database contained some pictures of the wheat.

4.2 User interface

User interface is the only communication between the system and its users. The target users of PRSRW were lab assistants, who were not good at computer. Therefore, the interface had been designed for facilitating easily access to input and update information. Users can also get the required information by selecting different conditions.

4.3 Inference process

Inference process simulates the intellectual process of the domain expert. It is the core of the expert system. PRSRW users could query the system using an inference process that automatically matched the fact.

For example, through the experiment, users got the resistance spectrum, and then system would process the comparison with the resistance spectrums which were already known. A possible resistance gene of the wheat would be found. System would automatically query the knowledge base and found out its pedigree. If pedigree analysis found out the same gene from its ancestor, the system would confirm the possible resistance gene and showed the result by the interface. If pedigree analysis could not match the fact, a further step would involve analyzing the integral information of the wheat. Through the integral information analysis, there would be two results. One was confirming the possible resistance gene; the other was not containing the gene and the system would suggest the user to contact the human experts directly. Toward all the steps, the system would explain the inference process and indicated the final result on the user interface. After a process of the postulation and inference of the resistance gene, the system would save the results automatically. Fig.2 showed the inference process of the system.

5. TESTING AND IMPLEMENTATION

System testing is important before the actual use. It is to ensure whether the system would work accurately or not. System testing, such as debugging, rule checking and system maintenance would be carried out by system developers.

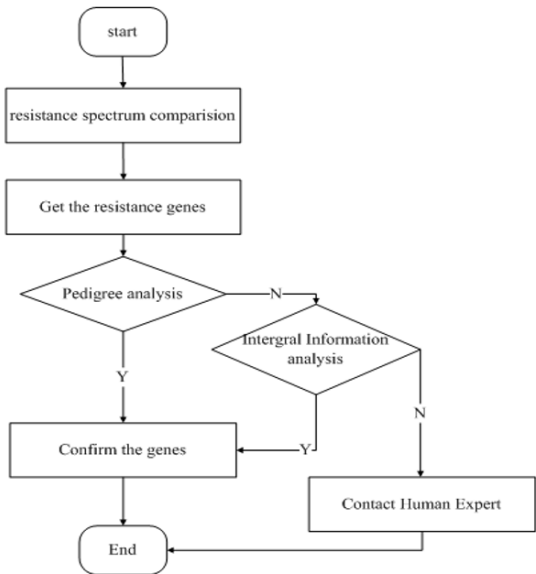


Fig.2: inference process of the system

The experiment data were collected from Chinese Academy of Agricultural Sciences, which is the research center of the wheat stripe rust. Some data were selected as the test data. After the system testing, user feedback was collected by conducting interviews. Totally, the system was an effective companion to lab assistant, human experts and other users.

Through some analysis of the system implementation tests and user feedbacks, the system showed the following characteristics:

The PRSRW expert system was regarded effectively in postulating and inferring resistance genes to wheat stripe rust, and it was saving users' time.

PRSRW was seemed as a useful tool for postulating and inferring resistance genes to wheat stripe rust. It could meet users' needs in different situation.

The friendly user interface was convenient and welcomed by users, and also the detailed comprehensive explanation of the result could help the users easily accept.

Some test results were showed in Fig.3



Fig.3: inferring result of the probable resistance gene

6. CONCLUSION AND DISCUSSION

In this research, an experts system called PRSRW was developed to postulate and infer resistance genes to wheat stripe rust. The System was able to facilitate experts to postulate and infer resistance genes quickly and accurately. The advantages were listed as following:

- PRSRW had a friendly user interface. It provided an easy way for the user accessing to the system, and also the expert could input and update the data information conveniently.
 - Knowledge base and integral database contained about 400 data and 34 gene information for different type of wheat cultivars. PRSRW saved the results that facilitate users to search and review.
 - PRSRW simulated the process of real human experts postulating and inferring the resistance gene by focusing on the resistance spectrum comparison and pedigree analysis.
 - Knowledge base and database from human experts had been combined with the system successfully.
 - PRSRW was designed as a multiple class user system. The low-level users only had parts of the authority to the system, while the high-level users had the whole authority.
- Of course, no system is perfect and the PRSRW also had some disadvantages, such as:
- PRSRW was a stand-alone system. It only could be installed or delivered to users who need it. With the rapid development of the Internet

and Intranet, a web-based system was convenient to the Internet users. Developing a web-based PRSRW would be our future work.

- Any expert system has limitations. Some problems might not be solved or achieve best results by PRSRW. A sub system should be developed that the users could communicate with the human experts directly.

In summary, postulation and inference of resistance genes to wheat stripe rust is a time-consuming job, and it often operates errors, the development of PRSRW could postulate and infer the resistance genes quickly and confirm the gene exactly. The research result demonstrated that the PRSRW was a valuable companion to dealing with the complexity problems.

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AGRICULTURAL MACHINES MANAGEMENT AND ASSIGNMENT SYSTEM OF HEILONGJIANG RECLAMATION AREA

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Abstract: To meet the need of modernization of agricultural machines management in Heilongjiang Reclamation Area, further boost the level of large-scale modernized agricultural production, and improve agricultural machines management, agricultural machines management and assignment network system has been established. The system has realized agricultural machines management by network and management departments of all levels can obtain the information of agricultural machine assignments on the internet. In this way, agricultural machine management has been improved.

Keywords: agriculture machines, agriculture information, network system.

1. PREFACE

At present, Heilongjiang Reclamation Area has become the largest national farm group where mechanization degree is the highest. Heilongjiang Reclamation Area takes modern agricultural machine equipment as direction and develops modern agriculture decisively. To meet the need of modernization of agricultural machines management in Heilongjiang Reclamation Area, further boost the level of large-scale modernized agricultural production, and improve agricultural machines management,

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agricultural machines management and assignment network system has been established. The system has realized agricultural machines management by network and management departments of all levels can obtain the information of agricultural machine assignments on the internet. In this way, agricultural machine management has been improved.

2. MANAGEMENT AND ASSIGNMENT SYSTEM OF AGRICULTURAL MACHINE

Management and command system of agricultural machines (Fig.1) is composed of command and management center, management network system, land block remote sensor material, farm geographical information system, GPS dynamic tracing system, remote video monitoring system, remote wireless video monitoring system for working machine, statistic and calculating of single unit workload, statistic of historical data for agricultural machine, experience communication system for machine usage, wireless data acquisition system for producing base environment etc.



Fig.1 Management and Command System of Agricultural Machines

2.1 Command and Management Center for Agricultural Machine

Command and management center for agricultural machine is centered with information management system. The center is cored by 3S (GPS、GIS、RS) technology and network technology. 126 inches plasma screen wall is used as display platform for machine management information and

video monitoring information. The plasma screen wall constitutes 3*3 42 inches plasma monitor screen. The size of the screen wall is 2880×1670×176 mm, and the system is equipped with 1 RGB matrix, 1 video and audio matrix, control computer for plasma screen, and 1 operation display computer.

2.2 Management Network System for Agricultural Machine

In order to meet the need of management modernization of agricultural machines, Heilongjiang Reclamation Area has boosted large-scale intensive modern agricultural productivity and agricultural machine management. At the same time, the Area has established network information system for agricultural machine management with internet technology. The current basic condition of management which includes management staffs, conditions of drivers, power machines management, conditions of agricultural equipment and management, historical data of machines etc can be recorded in management database for agricultural machines. The network management can not only allow management staffs to inquire on the internet but also bring convenience to superior management department for mastering the agricultural machine management information promptly.

2.3 Remote Sensing Material of Land Blocks

The satellite remote sensing images with graphics resolution of 2.5 meters can cover the whole farm land .After calculating on fixed point and geometry adjust, the ground position and space information which includes land blocks, roads, waters, forests, reservoirs, residences etc can be acquired. This facilitates general division of farm land and producing management. The remote sensing image data is transmitted to system server and the function including zooming out, zooming in, moving, distance calculating and land area calculating can be practiced through Web GIS software GeoBeans.

2.4 Farm Geographic Information System

By recognizing remote images and adjusting on the port, acquiring crop farming information relating to the space, the crop database can be established. The system can realize the function such as zooming in, zooming out, moving, land block inquiring, latitude and longitude of current position ,distance calculating, land area calculating etc by using Web GIS

software GeoBeans introduced from Remote Sensing Institute of Chinese Academy of Science . The basic condition and geographical position of certain number can be acquired on computer which has stored land map and land number information.

2.5 GPS Dynamic Tracing System

The working engines are equipped with GPS tracing equipment which can receive the current geographical information (latitude, longitude, height), time and moving status (speed, direction) by GPS receiver. The information can be transmitted to agricultural machine management database through GPRS. The working engine conditions including land block, direction, speed and working trace can be required on the internet and displayed on the screen of the center.

2.6 Remote Video Monitoring System

There is an infrared camera which can be rotated and its focus can be adjusted on the farm garage center. The network video server connects the internet and management staffs of all levels can monitor the farm garage condition so that garage management and fire and stealing can be prevented. The network video server is used to transmit digital video and audio signals through internet .The server adopts programmable high-speed digital signal processor (DSP) which can make the image transmitted with no delay and more clear. The management, configuration, and monitor and other operation else can be accomplished through Internet Explore.

2.7 Remote Wireless Video Monitoring System for Working Engines

The images of tractors or harvesters equipped with wireless video monitoring system can be transmitted to the management and command center through digital transmission equipment while they are working on the farm. Management staffs can monitor the current working condition of agricultural machines on the screen such as whether the machine is working or not and the equality of working etc.

The remote wireless video monitor on Red Star Farmland adopts COFDM technology. Image video and audio can be transmitted with no delay and the transmission distance can reach 20Km. The remote wireless video monitor on Seven Star Farmland adopts wireless local area network (802.11b、802.11a) technology. The system can transmit D1 format high-definition images to all directions or one certain direction. The working

machine which adopts 802.11b protocol transmits the images to the base station of management area which adopts 802.11a protocol. The images received from base station can be displayed on the screen.

2.8 GSM Short Message Group-Sending System

GSM is kind of global mobile communication system. Management and Command Center can send short messages to staff's mobile phone in a short time by using the GSM short message platform. The communication between the center and staffs in this way can lower much more communication costs and boost working efficiency. The staffs can receive the information reminded such as agricultural machine trends, new technology and maintain of machines on time by their own phones. This can facilitate organizing management, mobilizing of machines and promoting of new technology.

2.9 Assignment Schedule Statistics and Calculating System

Every administrative region can relay assignment schedule of each day of each period through computer network. The staffs in charge of management can get the assignment schedule information promptly and the system itself can also send machine-maintain requirement according to quantity of each machine.

2.10 Assignment Plan System

At the beginning of each year, the Management and Assignment Center puts forward the general design of machine's assignment according to the planting arrangement of the farm and organizes working machines to implement. The general plan of machines assignment including spring soil tillage, seeding, middle-planting management, harvest, autumn soil tillage etc can facilitate scientific management and organization of productivity.

2.11 Assignment Statistics and Calculating of Each Unit

The program designed for each unit assignment can calculate the quantity of assignment, accumulated incomes, accumulated oil consumption, accumulated output, standard oil consumption and costs of per unit. The information is input by administrative region and relayed to the Center.

Through exact assignment calculating of each engine unit, precise management can be attained.

2.12 Historical Material Statistic

The whole agricultural machines data such as the numbers of wheel tractors, pedrail tractors, matched agricultural machine equipments, harvesters, and total driving force etc can be required on the computer by program designed and displayed in the form of histogram or line chart on the screen.

2.13 Communication System for Experience

The experience communication website has been designed and staffs can exchange daily maintenance experience and technology improvement. If the new information and technology is input on the network, the drivers can acquire these on the internet at home.

2.14 Wireless Data Acquisition System

The production base of the farm is equipped with wireless environment data acquisition system which can acquire the environment data such as temperature, soil temperature, environment moisture, sunshine etc and then transmit the data to network database through GPRS. The staffs can browse the environment parameters on the internet and the system can provide support for production decision.

3. USAGE EFFECT OF THE SYSTEM

The Seven Star farm Research and Development Center and Red Star farm Modern Agricultural Machine Development Center on Heilongjiang Reclamation Area take the idea of “base upon precision agriculture and develop modern agricultural machines” as construction direction and intend to acquire the effects including saving of resource consumption in the largest degree and gaining the highest profit by high-technology devotion such as 3S technology (GPS, GIS, RS). The network information system is used to assign the work for all the machines. The management of agricultural machines is converted from dispersive, extensive management to intensive network management. The planters, machine owners, management staffs can inquire about production condition and assignment conditions, incomes and maintenance of machines on the internet. The new trend of agricultural

machines and technology improvement information can be sent to drivers by short messages. When the machines need to be examined and repaired, the workers can take the advantage of the computer in training room to inquire about technology information and exchange machine maintenance experience which can satisfy the technology need of staffs and boost the whole technology.

CONCLUSION

The construction of agricultural machine management and assignment system of Seven Star and Red Star farm in Heilongjiang Reclamation Area can adequately exert the advantage of large-scale modern agricultural machine assignment and boost the agriculture mechanism level. The system has brought network, digital and information to agricultural production on farmland. The scientific, standard, quantitative and high effective management can effectively promote the optimization of agricultural economic structure and pioneer new mode for exploring agricultural machine management under the new system and condition of China.

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A DECISION SUPPORT SYSTEM FOR EVALUATING QUALITY SAFETY RISK CONTAMINATED BY WATER POLLUTION IN AQUACULTURE POND

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Abstract: Water pollution is becoming the major factor damaging the sustainable development of aquaculture and the quality security of aquatic product in China. This paper introduces a decision support system for evaluating and managing quality risk contaminated by water pollution. The architecture, main components and their functions, especially a series of risk evaluation methods and models are described. At present, the system is in pilot in the city of Beijing in China. The stage achievements in developing the system are summarized.

Keywords: Decision support system, quality safety risk, water pollution, Aquaculture, evolutionary prototyping

1. INTRODUCTION

Aquaculture integrated into the smallhold farming system has been shown to improve both productivity and cash flows with little or no external

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input(Brummett and Noble,1995), is the fastest growing food-producing sector in the world and provides for almost 50 percent of the world's food fish requirements. As ocean stocks of wild fish diminish and fishing quotas are more strictly enforced, so farm-reared fish will continue to supply greater proportion of the growing consumption of aquatic food. Especially China produces about 70 percent of the farmed fish in the world, harvested at thousands of giant factory-style farms and has been transformed into the fastest-growing, biggest producer and exporter of fishery in the world over the past two decades.

But that growth is threatened by the two most glaring environmental weaknesses in China: acute water shortages and water supplies contaminated by sewage, industrial waste and agricultural runoff that includes pesticides, fish contaminated with toxic chemicals like DDT are already creating health problems. The fish farms, in turn, are discharging wastewater that further pollutes the water supply. Sometime Farmers have coped with the toxic waters by mixing illegal veterinary drugs and pesticides into fish feed, which helps keep their stocks alive yet leaves poisonous and carcinogenic residues in seafood, posing health threats to consumers(DAVID BARBOZA,2007).

Environmental degradation, in other words, has become a food safety problem, and the long-term risks of consuming contaminated fishery product could lead to higher rates of cancer and liver disease and other afflictions(DAVID BARBOZA,2007). Therefore, water quality pollution management are popular and important topics of fishery water environmental research due to the food quality security and health impact caused by exposing to water pollutants existing in aquaculture and preventive as well as evasive action execution during the episodes of waterborne pollution.

Obviously, there is an increasing interest and pressing need in an environmentally friendly culture to reach the development and dissemination of a range of fish culture systems that are both environmentally and economically sustainable. This paper introduces the development experience on the decision support system for quality risk evaluation and management contaminated by water pollution(WatPol) in aquaculture. The following is organized as: section 2 describes the development process; then the last section draws the conclusions and further improvement.

2. THE DEVELOPMENT PROCESS

For assuring ultimate success for developing WatPol, the evolutionary prototype mode had adopted as the development process or methodology taking into account prototyping process provides users with more opportunities to improve their work, to verify that their needs are provided

for, and that the terms used in the interface of the designed system are consistent with those in use in their work.

The following milestones outline the major tasks undertaken to develop the WatPol. A number of the tasks overlapped. The project was initiated in 2006 and the prototype was finished in 2007, which development process illustrates in Fig 1.

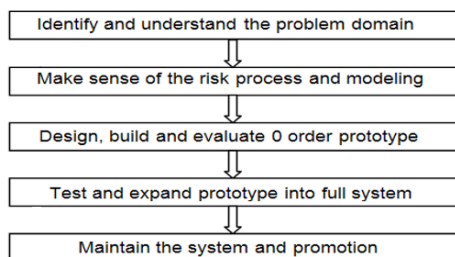


Fig1. the development process based on the prototyping model for WatPol

2.1 Identify and understand the problem domain

The first step in the project is to identify and understand the problem domain. It was the most complex and time-consuming part of the entire process. It requires working with many organizations or experts in order to get a handle on the structure and the content of expert system and determine the information that allow the problem domain to be defined correctly. The quality at this process leads directly to and impacts the success of last steps.

The problem had been identified by multiple methods in Beijing, Tianjin and Shandong:

1) Laboratory experiments. Fish are totally dependent upon water to breathe, feed and grow, excrete wastes, maintain a salt balance, reproduce, and understanding the physical and chemical qualities of water is critical to successful aquaculture. To a great extent water determines the success or failure of an aquaculture operation(Li Nan, et al,2007). Laboratory experiment aims not only to identify and rank the factor influenced the water quality and fish quality risk, but also to acquire the daily fluctuation via monitoring of pond water quality.

2) Experts questionnaires and interviews. The above methods can identify the relationship between water quality and fish quality safety, but it can't provide a risk management process and give a threshold for risk evaluation. The expert questionnaires and interviews aimed to further rank and weight the water quality factors, acquire the criteria for fish quality safety and the management process and strategies to reduce the losses. In the project, 22 experts from the domains of water quality and fish quality safety management were involved in a multi-step process of knowledge acquisition

by the method of Delphi. The response rate from experts was 65%. Reasons for this was that they were not interested or they could not find enough time as completing it took nearly one hour and must carefully think. Table 1 shows basic thresholds aquired from questionnaires.

Table 1. the grade of water eutrophication assessment

Grade	Trophic status(EI)
benchmark	[0-10]
I	Innutritive(10-13]
II	Nutritive(13-20]
III	Low-eutrophic(20-35]
IV	Medium-eutrophic(35-80]
V	High-eutrophic(80-95]

3) Literature review. A literatures review on water quality pollution, fish quality safety risk and modeling methods were conducted to provide a supplemental source of knowledge during system development to overcome the difficult caused by incomplete knowledge and data shortage. So that, the knowledge engineer could compare the different methods and develop the most appropriate and effective models to evaluate and forecast the water pollutant and fish quality safety risk.

2.2 Make sense of the risk evaluation and modeling

Based on the analysis on the information from step 1, the system development engineer and experts met several times to further understand the general practices more experts had accumulated the experience with the water quality and quality safety risk. The process is iterative and includes the following steps and models/methods.

Step1 the model/method for identifying the primary water environmental pollutants factors in Aquaculture pond. PCA(Principal component analysis) method was adopted to identify the primary water pollutant factors and reduce multidimensional data sets to lower dimensions for analysis.

Step2 the model/method for analyzing the relationship between water environmental pollutants and fish quality safety risk. The linear regression was adopted to model the relationship between two variables by fitting a linear equation to observed data. The selected of water environmental pollutants was considered to be an explanatory variable, and the quality safety risk index was considered to be a dependent variable.

Step3 the model/method for predicting the trend of water environmental pollutants acclimated in Aquaculture pond. Support vector machines (SVMs),a novel type of learning machine based on statistical learning theory, was adopted as the basic algorithm due that SVM achieves an optimum network structure by striking a right balance between the empirical error and

the VC-confidence interval. This balance eventually leads to better generalization performance than other neural network models(LI Nan, et al,2007).

Step4 the model/method for evaluating the probability the quality safety risks contaminated by water pollution. Monte Carlo methods were adopted as the basic methods. It is a class of computational algorithms that rely on repeated random sampling to compute their results. Because of their reliance on repeated computation and random or pseudo-random numbers, Monte Carlo methods are most suited to calculation by a computer. Monte Carlo methods tend to be used when it is infeasible or impossible to compute an exact result with a deterministic algorithm.

2.3 Design, build and evaluate 0 order prototype

2.3.1 Design and develop the prototype

A prototype system was built to test the functional specifications. Meetings with the system development engineer and experts were held until a consensus was reached on the objectives, constraints and specific tasks that the WatPol must perform to accomplish the design objectives.

B/S/S(Browser/Server/Server), which is able to better apply information system to network production, hardware platform and net compromise setting in different factories, was adopted as our system’s fundamental architecture to provide the transparency among the data layer, business logic layer and the user interface layer(ZHANG Xiaoshuan, etc,2006).

The models/methods developed in step 2 to perform the tasks had been coded into modules. Each module was described in terms of its basic algorithm and the required inputs, outputs, and knowledge sources(Fig 2, Fig 3). Benchmarks were established for completing the different modules. The end result was a design document, which aided in the planning and programming of the WatPol.

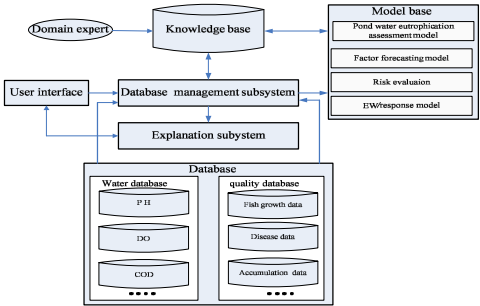


Fig 2. General framework of the software



Fig3. the interface of water eutrophication assessment

2.3.2 Evaluate 0 order prototype

Prototype evaluation process is fundamental in order to ensure the quality of the system and be convenient to the prototype expand the full system. After finished the Version 1.0, the system were promoted in several ways given that web-based systems had shown some benefits to easily accessible by users, enhance traditional explanation and justification functions with hyperlinks to other relevant sites and involve users in validation process.

- One was to send the introduction of the WatPol by emails or/and mails to the potential user and guide them directly logon on the website;
- Second was some workshops and trainings were held unusual;
- Another was to collect of user feedback via online forms and chat with the users via internet.

2.4 Test and expand prototype into full system

Based upon the design document, the prototype was expanded into the complete system. The actual and experiment data had been collected for the system test. Some users' feedback had collected. The following focuses the test based on the experiment data.

2.4.1 Experiment data collection

For evaluating and testing the system, a series experiments had been executed to acquire the test data from April to October,2006 in Beijing.

The water was sampled both from the external water suppliers and pond internal water. Not only the physical and chemical elements, but also the species composition including predominate species and biomass of planktons were sampled and tested.

The second experiment was responsible for collecting the daily data of the selected factors. It lasted from April to September in 2007. Water was sampled three times per day at 8:00 am, 14:00 pm and 20:00 pm respectively.

The last experiment was responsible for analyzing the fish quality safety. The pollutants factor found in the first experiment maybe accumulate in fish body and trigger oxidative stress in fish and affect their growth (J.E. Hinck, 2006). Nearly twenty fish per week were caught at random in each of the ponds. After capture, the livers, which was the main detoxification organ in fish (G. Deviller, et al., 2005), were dissected and weighed.

2.4.2 Data analysis and modeling

Step 1 identifying the primary water environmental pollutants factors

The result showed that the pond water was rich nutritive and the main pollutant of the pond water were non-ionic ammonia (NH_3), sulfureted hydrogen (H_2S), copper (Cu), cyanide (HCN) and Coliform during the experiment period.

In addition, after qualitative and quantitative analysis of phytoplankton, the results turned out that ninety-eight kinds of algae were detected in the pond, in which, 53% was Chlorophyta species, 34% was Bacillariophyta species, 8.2% was Cyanophyta species, 3.3% was Cryptophyta species and 1.5% was Pyrrophyta species.

Taking the COD as example, the concentration of COD_{Cr} in the pond water is affected by a series of factors, such as dissolved oxygen (DO), water temperature, water hardness (WH), nitrogen, phosphorus and so on. In this research, the principal factor analysis is used to select the most important factors as the input variables of the SVM network. The result of the principal factor analysis is shown in Table 2.

It can be concluded from the correlation analysis in Table 2 that water temperature (T), DO, and water hardness (WH) have remarkable correlations with COD_{Cr}, which means that the variation of them will affect the concentration of COD_{Cr} in the pond water. It also can be seen from Table 2 that the principal component coefficients of DO, water temperature and COD_{Cr} are higher than other factors in the first component. Although the principal component coefficients of water hardness and total phosphorus are high in the second and the fourth component, the contribution percentage is not high enough.

Table 2. Principal component analysis of pond water quality factors

	Principal component coefficient					Eigenvalue	Cumulative
	PH	T	DO	SD			
1	-0.16	1.14	1.26	0.07	0.30	3.16	0.40
2	0.46	-0.15	-0.04	0.44	0.73	1.48	0.58
3	-0.22	-0.49	0.17	-0.15	0.54	1.10	0.72
4	0.05	0.10	-0.20	0.44	-0.17	0.94	0.84

Step 2 analyzing the relationship between water environmental pollutants and fish quality safety risk(See Table 3).

Table 3. the regression model

Step	r ²	Paremeter	The regression model
1	0.53	X1=C _w	Y=0.32+0.58*X1
2	0.61	X2=PH	Y=0.36+0.61*X1-0.2X2
3	0.69	X3=WH	Y=0.46+0.53X1-0.16X2-0.00321X3
4	0.74	X4=FW	Y=0.5+0.47X1-0.13X2-0.00356X2-0.045X4

Where, C_w is the Cu⁺ density in water, WH is water hardness, FW is fish weight, PFC is forecasted Cu⁺ density in fish issue.

Step3 the model/method for predicting the trend of water environmental pollutants acclimated in Aquaculture pond.

Therefore, in this prediction experiments, DO, water temperature and COD_{Cr} are adopted as the input variables of the SVM network. In order to validate the feasibility of our hypothesis, five sets of input variables are considered and experimented, and the output is the level of COD_{Cr} in the next week. With comparing the Mean absolute error (MAE) and the Square root error, the best set of input variables is selected ultimately.

Fig 4 shows that the anova kernel has better generalization performance than other kernel functions on the testing process, which is in consistency with statistical learning theory.

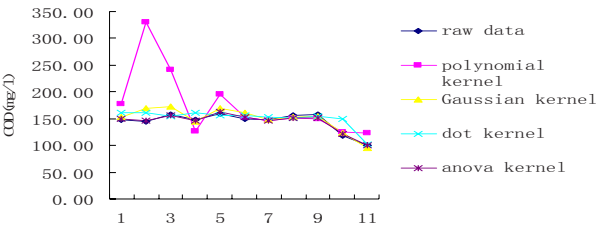


Fig 4. the SVM Kernel function selection

Step4 evaluating the probability of the quality safety risks contaminated by water pollution(Fig 5). It shows that uncertainties in the higher percentage point above grown exponentially. The risk of cumulative distribution function showed that the risk of contamination of aquatic products is less than 24% of the probability is 50 percent, 90 percent of the

probability of contamination of the instructions for the higher risk of 95 percent. Risk in 25% of the growth index that pollutants in the fish concentration is a positive deviation lognormal distribution.

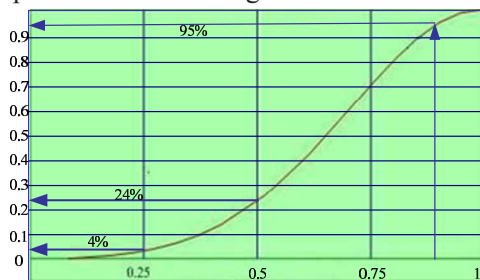


Fig 5. the probability evaluation of the quality safety risks contaminated by water pollution

2.4.3 The feedbacks from the experiment and test

The experiment test proves the system as an aid and a valuable companion for improving the quality of decisions making of the farmers and the extension officers involved in the fish quality safety and water environment management at farm level. The followings discuss and conclude some benefits and shortcomings for applying the system:

The benefits are the system can help to reduce economical losses due to fish quality safety risk by its continuous monitoring and real-time measurement of water quality and pollution with the characteristics of flexibility to adapt to users' requirements and increasing process efficiency.

The shortcomings are 1) WatPol is just applicable to Beijing given that the selected factors and the corresponding criteria are confirmed based on the special area. 2) WatPol can't evaluate the quality safety risk contaminated by water pollution not the feed and vermin.

In addition, the system should collect automatically or semi automatically the cases of fish quality safety and water pollution as much as possible. Then the system can be more effective by integrating more artificial intelligence, such as case-based reasoning.

2.5 Maintain the system and promotion

A long-term support and maintenance plan was devised. The system was designed so additional information or modules could be easily added. The WatPol is marketed, through Beijing Kuntai software Co. Ltd, a private soft engineering company that is interested in expanding its business interests in aquaculture and software systems. The company is responsible for marketing and distributing the software, as well as, providing technical software

support.

3. CONCLUSION

In this paper we develop multitasking software provides the ultimate in versatility for use in pond water pollution assessment, factor forecasting and fish quality safety risk assessment. The system can be used easily to explore the effect of different risk-reduction strategies.

Due that the factors are arbitrarily derived from case area, the system may not reflect reality all other of fish ponds. Whether the system is correct or not, the demonstration proved it was a powerful aid for teaching the principles of fish safety and can help train food safety managers to think in term of water pollution and fish safety risk.

The system is only seen as a prototype, not a definitive model. It needs be modified to suit the more broadly area and scenarios.

ACKNOWLEDGEMENTS

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APPLICATION OF COLORED PETRI NET IN MODELING OF AN AGRICULTURAL ENTERPRISE INFORMATION MANAGEMENT SYSTEM

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Abstract: Business system modeling of an agricultural enterprise is one of the difficulties in developing and researching an agricultural enterprise management information system. Given the inadequate description of concurrent and synchronal events in the traditional modeling methods, this paper presents a modeling method, which uses Colored Petri Net. The paper discusses the application of Colored Petri Net in system modeling with the example of an agricultural enterprise production management system model, and analyzes the feasibility and effectiveness of that model.

Keywords: Colored Petri net, CPN, Agricultural Enterprise Information Management, modeling, simulation

1. INTRODUCTION

Agriculture is the foundation of the national economy in our country. But at present the agricultural power of production still has a great disparity compared with some developed countries: the backward level of production technology, low high-tech content, weak market competitiveness, and the dominant traditional manual management during the process of agricultural

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production and management, etc. Therefore, accelerating agricultural information and modernization process, improving agricultural production management level, enhancing agricultural market competitiveness and achieving the sustainable development in agriculture have been a most pressing task before us.

An agricultural enterprise information management system is a very important tool adopted during the process of agricultural enterprises IT application. It has better function such as production plan management, marketing management, purchasing management, store control, distribution and delivery and DSS and so on. It is well known that a good business system needs a good model to support it. Establishing a model and analyzing it have two advantages (Chen et al., 2006). One is to check whether a model correctly reflects the features of the system modeled. The other is that it is of advantage to find some potential problems in designing a new system. Tools that could model business systems are more. Colored Petri net (CPN or CP-net) is one of them and it could describe concurrent and synchronal events better compared with other tools. A system model based on CPN could not only mask many details within the system but also clearly display many behavior properties. Business system modeling of an agricultural enterprise is one of the difficulties in developing and researching agricultural enterprises management information system. The paper discusses the application of CPN in system modeling with the example of an agricultural enterprise production management system model, and analyzes the feasibility and effectiveness of that model.

The rest of this paper is organized as follows. Section 2 gives the analysis of the features of an agricultural enterprise information management system. Section 3 is devoted to the relevant definitions of Petri net and colored Petri net. The method about how to model a business system is introduced in Section 4. And analysis and simulation of the model are presented in Section 5. Finally, in Section 6 we briefly evaluate the model based on CPN.

2. ANALYSIS OF FEATURES OF AN AGRICULTURAL ENTERPRISES INFORMATION MANAGEMENT SYSTEM

Generally the business process of an agricultural enterprise includes some links such as purchasing management, store management, production management, marketing management, cost control and so on. It is found from the process that the management information system to be modeled is very complex. And it is also discovered that flexibility, concurrency and

hierarchic structure are the most content after researching the structure and behavior properties of this system. At the same time these are also the keys to study in modeling.

Here system flexibility refers to the variety of products of an agricultural enterprise, this is to say, the products managed by the system to be modeled have great varieties. So an effective way is needed to model these varieties. It is interesting that the colored sets of CP-nets could be just used to describe those varieties. System concurrency is the property about the concurrent process of production management. For example, the production order and supply order of a type of product enter into the workshop and warehouse respectively at some time. This property could bring into many synchronal problems which happen dynamically. When it is coming to system hierarchic structure, it means that all the links of business process of an agricultural enterprise are very complicated, this is to say, it is made up of interactive sub modules or sub systems.

Above all, the system model using CPN could effectively describe the properties of flexibility, concurrency and hierarchic structure.

3. RELATION DEFINITIONS OF COLORED PETRI NET

Petri net targets researching organization structure and dynamic behavior, and aims at the state changes, which may happen in the system, and the relation among these changes. It could accurately describe concurrent and distributed systems (Liu et al., 2006). Relevant definitions of CPN are shown below.

Definition 1 (Petri net) (Wu et al., 2006, Yuan et al., 1998, Brauer, 1980): In a formal way, a Petri net is a 3-tuple: $PN = (P, T, F)$. Where:

- (1) P is a finite set of Places;
- (2) T is a finite set of Transitions;
- (3) F is a finite set of Arcs such that: $P \cap T = P \cap F = T \cap F = \emptyset$.

A colored Petri net extends a general Petri net, with adding colored sets and declarations. It could be more flexibly suitable to model the application of system business.

Definition 2 (Colored Petri net t) (Wu et al., 2006, Yuan et al., 1998, Jensen, 1997, Jensen, 1998): In a formal way, a colored Petri net is a 9-tuple: $CPN = (\Sigma, P, T, F, N, C, G, E, I)$

- (1) Σ is a finite set of non-empty types, also called colored sets;
- (2) P is a finite set of Places;
- (3) T is a finite set of Transitions;

- (4) F is a finite set of Arcs such that: $P \cap T = P \cap F = T \cap F = \emptyset$;
- (5) N is a node function. It is defined from F into colored over arcs $P \times T \cup T \times P$;
- (6) C is a color function. It is defined from P into $\sum$ token;
- (7) G is a guard function. It is defined from T into expressions such that: “Boolean function with probability”

$$\forall t \in T : [Type(G(t)) = B \wedge Type(\text{var}(G(t))) \in \Sigma];$$

- (8) E is an arc expression function. It is defined from F into expressions such that:

$$\forall a \in F : [Type(E(a)) = C(p)MS \wedge Type(\text{var}(E(a))) \in \Sigma]$$

Where p is the place of $N(a)$

- (9) I is an initialization function. It is defined from P into closed expression such that

$$\forall p \in P : [Type(I(p)) = C(p)MS]$$

Definition 3 (Substitution Transition) (Jensen, 2008): Creating large, intricate nets can be a cumbersome task. But similar to modular programming, the construction of CP-nets can be broken into smaller pieces by utilizing the facilities within CPN Tools for creating substitution transitions. Conceptually, nets with substitution transitions are nets with multiple layers of details – you can have a somewhat simplified net that gives a broad overview of the system you are modeling, and by substituting transitions of this top-level net with more detailed pages, you can bring more and more details into the model.

Definition 4 (P-invariant and T-invariant) (Wu et al., 2006, Jensen, 1998): Given a Petri net: $N = (P, T; F)$, $|P| = m$, $|T| = n$, A is the incidence of this net. Any nonnegative integer solution Y of the equation $AY = 0$ is a P-invariant, where Y is a column vector. Any nonnegative integer solution X of the equation $A^T X = 0$ is a T-invariant, where X is a column vector.

P-invariant and T-invariant could analyze the properties of Petri net such as liveness and boundedness and as on.

4. MODELING USING CPN

Modeling the whole business system of an agricultural enterprise is complex. This section contains an example that models a production

management system, one part of agricultural enterprises business management, in order to discuss how to model using colored Petri net. The key method to model this system is as follows.

At first, it is possible to give a whole system design but not to consider the details of the links of the system. Then build a top model based on CPN according to its hierarchical property. Finally model the details of those links respectively. If so the number of Places and Transitions of the model will decrease sharply and the model graph will be more concise.

Generally production management has two models (Wang et al., 2006). The first one is push model, for example MRP, which makes the input and output plan of every part according to the requirement of main production plan and issues production or order instructions according to this plan. Every work center builds its parts relying on the plan and sends its parts finished to its following work center. The second one is pull model, for instance JIT (Wang et al., 2006), which begins from the orders on behalf of customer needs and works out the main production plan and the assembly plan according to demands of the market. Every work center requests the former center and issues work instructions in accordance with the need for parts at the time. The former center works according to these instructions completely. This anti-process sequence pulls step by step the former work centers even supply factories or collaborative factories. This paper will model this "pull" production management system.

The basic assumptions for modeling are as follows

- (1) There are two kinds of materials in the warehouse. Raw materials are for processing and the other material for packaging.
- (2) Product warehouse has one produce.
- (3) Semi-finished warehouse has one produce.
- (4) Time for procurement, stock and delivery is so much less that they can be ignored.
- (5) All orders can be available.
- (6) The material loss and waste rate is equal to zero.

The top model of a production management system is shown below.

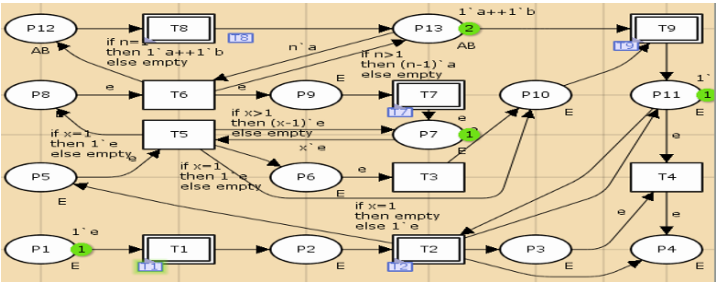


Fig.1. Production management system model

Table 1. and Table 2. show the Places and the transitions of the model respectively.

Table 1. Places of the model

Places	Definitions	Places	Definitions
P1	User order	P2	Invoice
P3	Waiting invoice	P4	Satisfied order
P5	Package list	P6	Waiting package list 1
P7	Warehouse for semi-finished products	P8	Product order
P9	Supply order	P10	Waiting package list 2
P11	Warehouse for products	P12	Purchasing order
P13	Warehouse for materials		

Table 2. Transitions of the model

Transitions	Definitions	Transitions	Definitions
T1	Transmit user order	T2	Process use order
T3	Transmit package list	T4	Stock out
T5	Process package list	T6	Process purchasing order
T7	manufacturing	T8	Purchasing management
T9	Package management		

Where: T1, T2, T7, T8 and T9 respectively are a Substitution Transition, and are on behave of their corresponding sub page.

5. MODEL SIMULATION AND ANALYSIS

Analysis and simulation are the main two ways to evaluate a model. Analysis is to analyze the properties of the model. Generally the properties discussed have boundedness, reversibility, and liveness, etc. these can be analyzed by P-invariant and T-invariant.

The incident matrix of the net shown in Fig.1 can be drawn.

$$A = \begin{pmatrix} -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 1 & 0 \end{pmatrix} \tag{1}$$

According to the equation $AY = 0$, we can get P-invariants.

$$Y_1=(2, 2, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0)^T \tag{2}$$

$$Y_2=(1, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0)^T \tag{3}$$

Clearly the net of the model is correct. It is also clear that for every reachable marking μ we can have

$$\begin{aligned} &\mu(p1)+\mu(p2)+\mu(p5) \\ &= \mu_0(p1)+\mu_0(p2)+\mu_0(p5)=1 \end{aligned} \tag{4}$$

where μ_0 is the initial marking. So there exists a P-invariant Y with $Y(p) > 0$, for each $p \in P$, the colored Petri net is bounded (Jensen, 2008, Zhang et al., 1998, Özgür ARMANERİ, 2006).

According to $A^T X = 0$ we can get a T-invariant.

$$X=(0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0)^T \tag{5}$$

All elements of T-invariant are equal to zero. Then it is claimed that is impossible to come back to the initial marking after firing a sequence of transitions. From a manufacturing point of view, this means that it will be impossible to come back to the initial state if we perform the operation represented by the transitions. So this colored Petri net is not reversible.

Simulation means that the system model can be simulated to operate by using a program to get its function analysis and evaluation. After establishing the model, it can run correctly (shown in Fig.2 in the left) through the function of symbols checking and imitation of CPN Tools, so this model is right. And there does not exist any deadlock, so it is also live. The result of simulation (shown in Fig.2 in the right) also shows that we can get the correct result.

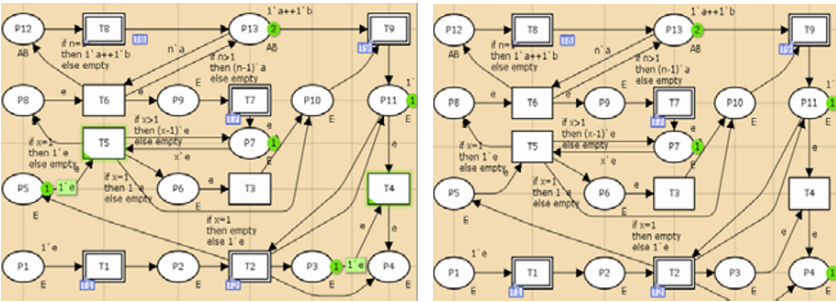


Fig.2. Simulation of a model of product management

6. CONCLUSION

Modeling an agricultural production management using colored Petri net and simulating the model using CPN Tools are presented in this paper. The paper also analyzed the properties of liveness, deadlock, boundedness, etc. of this model. The result of analysis and simulation shows that it is feasible and effective to model an agricultural enterprise business management using colored Petri net.

Using colored Petri net can make our research more overall and deeply, and our models more concise and clear. And it also has a very important application value to develop the system later. Because the concept of time does not be introduced into the system model, the evaluation of system performance could not get better. And this work will also be done in the next research. Of course we can also model other links of an agricultural enterprise business management, and this will build a good foundation for modularization and hierarchy for the structure of the management software.

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DESIGN OF DECISION-MAKING SYSTEM ABOUT WHEAT SURVEY AND DIRECTIONS FOR SOIL BASED ON GIS IN COUNTY

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Abstract: With consideration of the decentralization of wheat fertilization management and status in quo in Henan province, the paper mainly designed county wheat decision-making System of survey and directions for soil Based on GIS. By collecting 3773 records of survey and directions for soil in 976 vilages, Hua county, protracting all kinds of vectorgraphs about villages, towns and the soil survey points, and using nutrient balance and model of survey and directions for soil and wheat fertilization directions, the paper had analysed and designed the system of survey and directions for soil and wheat fertilization directions integrating OOP, software component technique, GIS and so on, realized query for information of soil survey points and estimation for soil nutrient distribution and decision-making for wheat fertilization directions, and provided technology support for application of crop survey and directions for soil in Henan province.

Keywords: survey and directions for soil, county wheat fertilization, crop nutrient balance, fertilizing decision-making system, GIS

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1. INTRODUCTION

Survey and directions for soil is one of important technologies of precision agriculture, and developmental direction of scientific fertilization in agriculture production currently, and also an enriching engineering of agricultural science and technology to farm generalized by Ministry of Agriculture (Yang Bin et al., 2007; Liu Yan et al., 2007).

With consideration of the decentralization of wheat fertilization management and status in quo in Henan province, the paper mainly designed county wheat decision-making System of survey and directions for soil Based on GIS. Making administrative villages the units and survey and directions for soil and wheat fertilization the research object, the paper adopted the nutrient balance model and survey and directions for soil model, researched wheat precision fertilization, and realized wheat fertilization management system by using computer technology、GIS and net database, which realized special subject analysis for monitor points fertility and county wheat decision-making fertilization application and played a very important instructional role to agriculture production (Wu Haoxiang et al., 2007).

2. DATA SOURCE AND RESEARCH METHOD

Taking Hua county as an example, the paper had collected 3773 soil nutrient records of each village's 4 azimuth in 22 towns by using GPS and rapid test instrument of soil nutrient, and constructed soil nutrient database. According to traditional agriculture production, the system adopted the nutrient balance model and survey and directions for soil model.

3. SYSTEM DESIGN

3.1 System hiberarchy

Introducing Client/Server/DBMS which separates the logic service from the user connection , the system is made up of database service level, function components level and intergration components level (Xi Lei et al., 2005; Xi Lei, 2003; Zhang Hao et al., 2007). Fig.1 shows the system hiberarchy. Function components which is based on system service level consist of standalone function component in logic each other. Function components of the system is made up of information query model,

information statistic model, information summary model, special subject analysis model, manuring decision-making model, and information collecting model. Accordingly intergration components level is made up of information query intergration model, information statistic intergration model, information summary intergration model, special subject analysis intergration model, manuring decision-making intergration model, and information collecting intergration model.

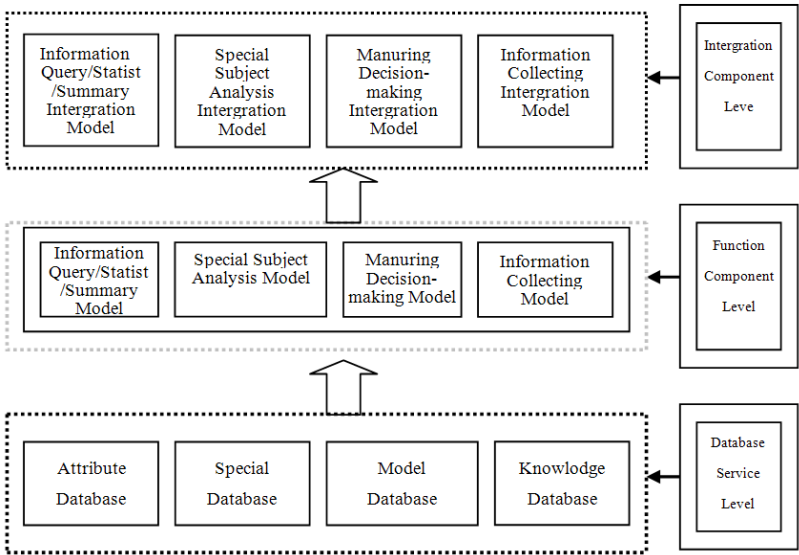


Fig. 1: System hiberarchy

3.2 Design of System Function

A The system function includes data management, information statistic and summary, special subject analysis, wheat manuring decision-making, wheat manuring recommend program and print, user permission management and system help, and so on. Fig.2 shows the system function structure.

- Data management
Management of system running data which includes spatial information and attribute information.
- Information statistic and summary
Including vectorgraph and attribute value query each other, statistic and summary of all kinds of information.

- Special subject analysis
Special subject analysis including microelement such as Cu, Ca, Mn, and so on, macroelement such as N, P, K, and so on, organic matter, and so on.
- Management of wheat manuring decision-making model
- Wheat manuring recommend program and print
According to monitoring point nutrient information and wheat output target, the system arrives at unit manuring recommend program and advice output of manuring measurement and fertilizing technology.

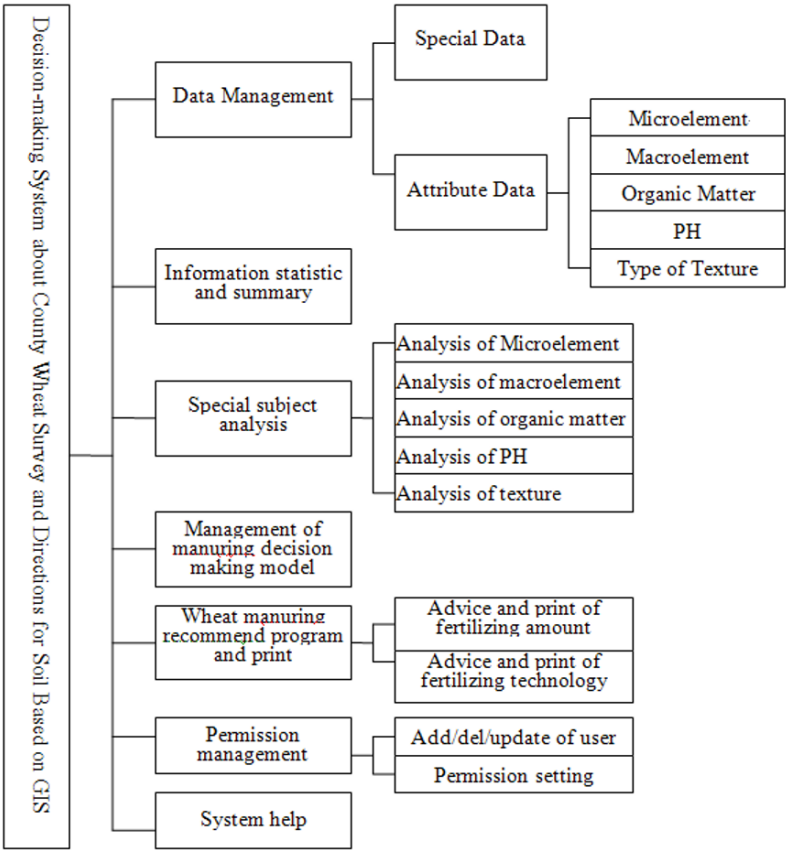


Fig.2: System function structure

3.3 Design of wheat recommend manuring model

Routine crop fertilizing models include ASI nutrient grade (Yang Liping et al., 2000; Xiong Guiyun et al., 2007), nutrient balance (Sun Mengjun et al.,

1989) and land capability subtraction (Zhou Shangzhi et al., 2003). The system used nutrient balance model. Recommend fertilizing result includes fertilizing program, fertilizer class choice and main nutrient content conversion of future organic. In practice, in order to fertilize expediently, the paper only considered N, P and K element. Formula 1 shows the nutrient balance model (Xie Gaodi et al., 2005; He Liyuan et al., 2007):

$$M=(U \times T-S)/P/C \quad (1)$$

Where: M is manuring measurement; U is nutrient element sorbability pre 100kg crop, which is queried from table of crop nutrient sorbability; T is target output, which is divided into 3 grades: 450 ~ 500kg/acre, 500 ~ 550kg/acre, and above and beyond 550kg/acre, according to the soil output capability; S is soil nutrient supply, which equals to soil nutrient value multiplied by 0.15; P is fertilizer absorptivity, which is queried from table of fertilizer class; C is fertilizer nutrient content, which is queried from table of fertilizer class.

3.4 Data Collection and Database Structure Design

3.4.1 Data Collection

System Data includes attribute data and spatial data. Attribute data table includes soil monitoring point, wheat variety, administration regionalization and farmer information. Soil information of monitoring point is made up of soil texture, total nitrogen, alkali-hydro nitrogen, P_2O_5 , K, Organic matter, PH, and so on. Administration regionalization table is made up of 22 towns and 976 administrative villages. By 1:10,000 scale, the system used ArcView to build spatial database.

3.4.2 Database Structure

Database design is the key of effective working and function implement of GIS (Yang Bao-zhu et al., 2005). This system database designed by adopting E-R model mainly includes the spatial character database, the attribute characteristic database. Fig.3(a) shows the system database structure. Fig.3(b) shows the database structure of attribute character, and Fig.3(b) shows the database structure of spatial character.

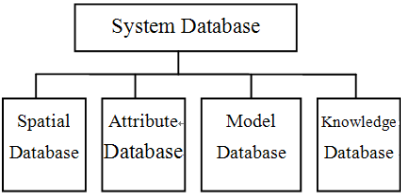


Fig.3(a):System database structure

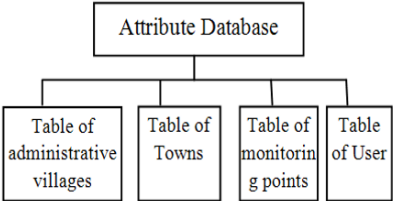


Fig.3(b):Attribute database

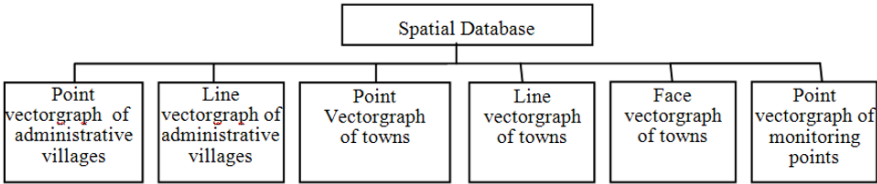


Fig. 3(c):Spatial database

3.4.3 Attribute database Design

Attribute database is mainly made up of administrative village table and monitoring point table. Table 1 and Table 2 show the data table design of administrative village and monitoring point.

Table 1 Design of administrative Village

Field Name	Field type	Primary/Foreign key or No	Repeated or No	Empty or No	Index or No	Explanation
ID	Char 10	Primary key	No	No	Yes	Village ID
Village_Name	Char 10	Foreign key	No	No	Yes	Village Name
Town_Name	Char 10	Foreign key	No	No	Yes	Town Name
Longitude	Float 8	Foreign key	Yes	No	Yes	Longitude
Latitude	Float 8	Foreign key	Yes	No	Yes	Latitude
Soil_Area	Float 8	No	Yes	No	Yes	Soil Area
Soil_Potential	Float 8	No	Yes	No	Yes	Soil Potential
Input_Time	Datetime	No	Yes	No	No	Input Time
Recorder	Char 10	No	Yes	No	No	Recorder

Table 2 Design of monitoring point

Field Name	Field type	Primary/Foreign key or No	Repeated or No	Empty or No	Index or No	Explanation
ID	Char 10	Primary key	No	No	Yes	Point ID
Uni_ID	Char 20	Foreign key	No	No	Yes	Uniform ID
Labouratory_ID	Int 4	Foreign key	No	No	Yes	Labouratory ID
Longitude	Float 8	No	Yes	No	Yes	Longitude
Latitude	Float 8	No	Yes	No	Yes	Latitude
Village_name	Char 10	Foreign Key	Yes	No	No	Village Name
Orientation	Char 10	No	Yes	No	No	Orientation
Soil_Texture	Char 10	No	Yes	No	No	Soil Texture
Organic_Matter	Float 8	No	Yes	No	No	Organic Matter
Total_Nitrogen	Float 8	No	Yes	No	No	Total Nitrogen
Rapid_Avail_P	Float 8	No	Yes	No	No	Rapid Available P
Rapid_Avail_K	Float 8	No	Yes	No	No	Rapid Available K
Slow_Avail_K	Float 8	No	Yes	No	No	Slow Available K
PH	Float 8	No	Yes	No	No	PH
Input_Time	Datetime	No	Yes	No	No	Input Time
Recorder	Char 10	No	Yes	No	No	Recorder

4. SYSTEM REALIZATION

The system is realized by using data driven as method, Visual Basic 6.0 as development, MapObjects as component (Chen Zheng-jiang et al., 2005; Chao Zhang, 2007; Mchael Zeiler, 1999), and SQL Server 2000 netdatabase, soft-component, following development standard of COM/DCOM and OOP. The realized system can be set up and run on Win 20000/2003、Win XP、Win NT in PC and touch screen system.

Considering distributed continuity of soil and easy acquisitiveness of soil information, the research of the system made each administrative village the units, collected soil point information of 4 trends of each village, produced soil monitoring point vectorgraph with Arcview. After selecting points on the system(Fig 4), the system makes buffer analysis on selected point. Farmers can select the nearer points close to the selected point from the buffer, and make formula fertilizing amount decision and fertilizing technology decision(Fig 5).

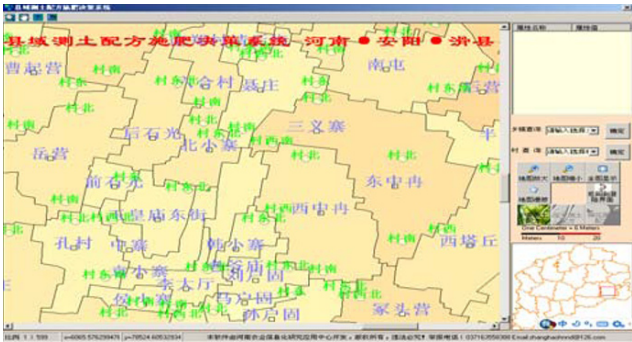


Fig.4.System point selection interface



Fig.5.Wheat decision-making fertilizing interface

5. CONCLUSION

The system had been applied in Hua county agriculture production. Base on the principle of systematization, friendly operating, expansibility and easy application, the system made use of high technologies, and realized scientific management on wheat survey and directions for soil and decision making analysis on wheat production, which has provided technology support for application of crop survey and directions for soil in Henan province.

According to the situation of the soil fertility distribution differentiation at the same trend, the collected soil monitoring point maybe does not represent all plots at the corresponding trend. To resolve the question, it is feasible to select 6-10 representative soil monitoring points at each trend, analyze them on density based on GIS, filter representative and precise monitoring points, and make variable farmland nutrient vectorgraph finally, so that the system

increases the wheat decision-making precision of survey and directions for soil.

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ANALYSIS AND ASSISTANT PLANNING SYSTEM OF REGIONAL AGRICULTURAL ECONOMIC INFORMATION

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Abstract: For the common problems existed in regional development and planning, we try to design a decision support system for assisting regional agricultural development and alignment as a decision-making tool for local government and decision maker. The analysis methods of forecast, comparative advantage, liner programming and statistical analysis are adopted. According to comparative advantage theory, the regional advantage can be determined by calculating and comparing yield advantage index (YAI), Scale advantage index (SAI), Complicated advantage index (CAI). Combining with GIS, agricultural data are presented as a form of graph such as area, bar and pie to uncover the principle and trend for decision-making which can't be found in data table. This system provides assistant decisions for agricultural structure adjustment, agro-forestry development and planning, and can be integrated to information technologies such as RS, AI and so on.

Keywords: regional agriculture, economic information, comparative advantage, decision-making

1. INTRODUCTION

Now computer has been used to analyze and make assistant decision for agricultural economic information in a large scale. There are many research achievements and application system at home and broad such as continuable

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decision support system for optimizing water and nitrogen management, taxation system for evaluating the effect of nitrogen on environment, basin water use model, vegetation variation model resulted in agricultural policy, microeconomic model for reflecting the land-use change of outskirts between town and suburb, land-cover change model in Honduras, regional agricultural advantage industry analysis and assistant decision-making for planning agricultural development. These systems and models involve matters of land use, crop management, water and soil conservation, hydrology, soil erosion, ES, GIS, environment pollution, water resource distribution, agroecology, social economy and mathematic model(Montas and Madramootoo, 1992; Polman and Thijssen, 2002; Rosegrant, et al, 2000; Müller and Zeller, 2002; Bell and Irwin, 2002; Munroe, et al, 2002; Zhu Ye-ping, 2007, Xue Yan,2007). In the respects of farm management, wood production, oil plants production and deforestation, systems and models such as layout and decision-making support system for moderate farm (AgriSupport II), management information system of cattle farm, decision support system for producing wood block, oil seed production and processing competition model between regions, space-time model of felling tropic forest in South Mexico have been constructed, which used time series aerial images, investigation data of farmers located by GPS, space balance model, competition difference between regions, shadow price, MS Excel and linear programming to resolve corresponding problems(Vance and Geoghegan, 2002; Omoregie and Thomson, 2001; Buehlmann, et al, 2000; Tomaszewski, et al, 2000; Recio, et al, 2003). Van Tongeren et al (2001) evaluated 16 models related to agriculture and trade policy. As to planting structure adjustment, the systems and models of natural resource and planting structure information system in Shanxi, risk decision model, resourceful planting institution decision system, decision support system for adjusting regional planting structure, planting institution decision support system, decision support system of planting structure adjustment and so on involving GIS, statistical analysis, WTO regulation, WebGIS, ecological evaluation model of agricultural resource, model for estimating agricultural productivity level, optimum design model of planting structure and reasonable layout, space data clustering, correlation analysis of space data and time mode analysis have been constructed(Song, 2001; Du, 2001; Wang, 2003; Qin, 2002; Peng, 2003; Qiao, 2003). China Academy of Sciences built continuable agricultural decision support system for Jianli county of Sihui region in 2000(Wang, 2000). The researches on analysis and assistant planning system of regional agricultural economic information at home and broad are promoted continuously with the development of information technology. Yet the application of artificial intelligence in macroscopically decision support system is not highly popular. Constructing

analysis and assistant planning system of regional agricultural economic information based on artificial intelligence by integrating the theories and technologies of agricultural economy, geography, computer and agronomy will provide help for regional agricultural development as a practical, intelligent and network tool, therefore will contributed to the food safety, yield increase and farmer's income increase.

2. ANALYSIS MODELS FOR REGIONAL AGRICULTURAL ECONOMY

When analyzing regional agricultural economic information, we must first determine the region need to be analyzed, then should confirm the factors. After comparing the relative data from this region with ones from the areas around the region, we can make sure the regional advantage, which would be given full play to plan regional development and forecast the future development to test its feasibility and validity. Aiming at the common problems existed in regional development plan; this study wants to design a decision support system for assisting regional agricultural development and display as a decision-making tool for local government and decision maker. The analysis methods of forecast, comparative advantage, liner programming and statistical analysis are adopted.

The model technologies used in the system include the technologies of time series forecast, non-liner forecast, comparative advantage analysis of agricultural economic data, measure and calculate analysis of agricultural economy, dynamic correlation analysis for agricultural economic data, development index analysis of agricultural economy, special analysis for agricultural economic data and so on.

2.1 Input-output analysis model for agricultural economy

From the angle of entire agricultural economic system, by using input-output analysis method and equation, input-output analysis model analyzes the relationship among planting, forestry, stockbreeding, fishery and the other sections, and analyzes the input-output quantity relationship between agricultural sections and the sections of other industry, explores the economic connection between agriculture and other sections, among the each section in agriculture quantificational based on input-output tables of provinces.

2.2 Analysis of agricultural industry structure

Combination proportion and mutual relationship of farming, forestry, animal husbandry, fishery and their internal sections are analyzed.

The 6 layers are listed as below.

1. The ratio of single industry i.e. farming, forestry, animal husbandry or fishery to total industries.
2. The ratio of one production to the other in certain industry. For example, the proportion of bread corn and cash crop production in total farming as a whole; the proportion of cattle cultivation and livestock and poultry output in total animal husbandry.
3. Agricultural products structure, i.e. the proportion of different agricultural product in the same category.
4. Variety structure in the same agricultural product.
5. Quality structure in the same variety of agricultural product. For example, the number of high quality Fuji apple among the total ones.
6. Time structure for the same agricultural product to come into market.

2.3 Comparative advantage analysis

According to the comparative advantage theory, production factors, natural resources, specialization level, and their changing regional difference generate the comparative advantage among regions, which is weighted with the economic competitiveness of certain goods produced by a nation, region, manufacturer or person compared with other producer. Through calculating below comparative advantage indexes, the author analyzes the regional advantage industry and provides planning service.

Yield advantage index (YAI)

$$A_{ij} = (y_{ij}/y_i) / (Y_j/Y) \times 100 \quad (1)$$

Where, A_{ij} is the YAI of j crops in region i , y_{ij} is the average yield of j crops in region i , y_i represents the average yield of all crops in region i , Y_j represents the yield of j crops around China and Y represents the average yield of all crops around China. Relative comparative advantage under 100 means there is no advantage in this region. Relative comparative advantage above 100 means there is advantage in crop yield.

Scale advantage index (SAI)

$$B_{ij} = (s_{ij}/s_i) / (S_j/S) \times 100 \quad (2)$$

In this formula, B_{ij} is the SAI of j crops in region i , s_{ij} is the planted area of j crops in region i , s_i represents the planted area of all crops in region i , S_j represents the planted area of j crops around China and S represents the planted area of all crops around China. In fact SAI is the ratio of the

proportion of planted area of certain crop in total areas in a province to the proportion of planted area of certain crop in China, i.e. location quotient. In general, location quotient above 100 indicates this province possesses fair specialization centralization. The more the location quotient is, the higher the specialization centralization is.

Complicated advantage index (CAI)

$$C_{ij}=(A_{ij} \times B_{ij})^2 \quad (3)$$

YAI represents agricultural comparative advantage from the angle of productivity mainly.

2.4 Space analysis of regional agricultural economy

Agricultural economic data are combined with GIS in order to make full use of its analysis and expression ability to deal with data directly. Agricultural data are presented as a form of graph to uncover the pattern and trend for decision-making which can't be found in table.

The author divided the agricultural economic data to two grades according to area. One is the data of different province, city and autonomous region. The other is the data of different county in certain province or city. These data are analyzed and expressed with special map of GIS, which include three types in accordance with rendering mode.

They are: Areal map, which groups the total records according to area, and gives each record corresponding color and symbol. The group number can be adjusted in order to reach optimum effect. Bar chart, which includes several variables to distinguish the colors and analyze at the same time. Bar height represents the variable value. In general bar chart with 4 to 6 bars performs well. Pie chart is also multi-variable special map.

2.5 Optimum model for regional agricultural development

The main body of agricultural structure adjustment is farmer, yet it is government in planned economy age. Government adjusts purchase price and farmer changes the variety and planted area according to market price. Agricultural structure adjustment aims to the most income of farmer, and not the highest amount of agricultural products. The target function of liner programming model is the highest farmer's income. Farmer gets the highest income through adjusting the decision varieties of planted area of crop and labor input. The regulative direction and quantity can be determined after

comparing the planted area with that before adjustment. So farmer's income should be calculated.

The common formula for liner programming model is:

$$\text{Max } Z = \sum_{i=1}^n c_i x_i \quad (4)$$

Restriction conditions are:

$$a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n \leq b_1 \quad (5)$$

$$a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n \leq b_2 \quad (6)$$

$$a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n \leq b_m \quad (7)$$

$$x_1 \geq 0, x_2 \geq 0, \dots, x_n \geq 0 \quad (8)$$

When planning agricultural structure, a large of liner programming models is adopted. The models resulted from different angle are various. Even if in the same model the parameters of a_{ij} , b_j and c_i vary with the application region. Researcher must modify the model parameters on the basis of regional characteristics in a practical analysis.

3. SYSTEM ARCHITECTURE

Constructing agricultural information platform should consider the performance factors of practicability, safety, standardization, advance and extensibility and so on.

The system uses the popular light weight Java EE SSH frame as basic technology structure. System architecture is based on B/S structure, which is apt to deploy and maintain has lower requirement for client. Interface and operation are easy to separate because of the clear program structure.

Because a large quantity of factors and algorithms are involved in this system, this study emphasizes system design and technology realization. The specific functions will depend on later research. Considering the system extensibility, system designs multi-subsystems structure based on knowledge. After allocating the task of every subsystem, the system tries to resolve different problems by using same knowledge. System structure that includes 5 layers of basic information, information management, task requesting, task assignment and communication, user is shown in Fig 1. Each layer consists of some subsystems which can be added and deleted further.

Analysis and assistant planning system of regional agricultural economic information proposed in this study can not only be used for forecast and decision making by analyzing the industry structure of farming, forestry and

animal husbandry in different region, but also be applied to analyze the matters of agricultural structure adjustment, returning plough land back to forest and grassland, agro-forestry production planning and provides assistant decision.

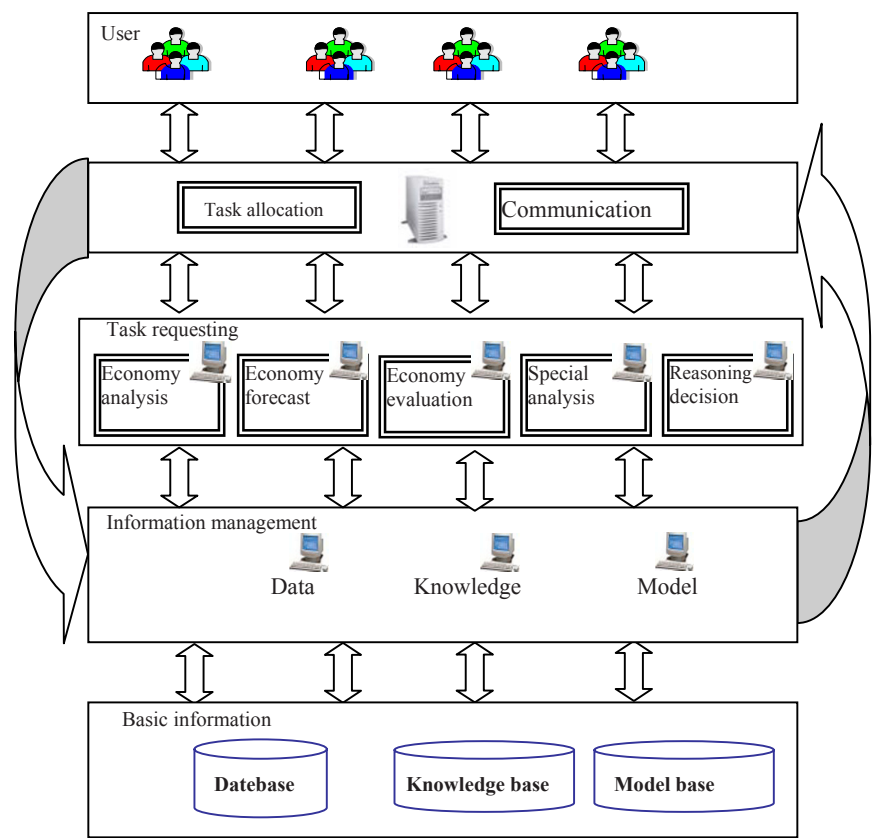


Fig 1. System architecture

4. CONCLUSION

As we know, BP neural network can be used to predict the stress-strain relationship for oilseeds, which not only overcomes the difficulty for theoretical model development, but also avoids requiring considerable technique and experience for nonlinear regression analysis. No more than 0.0084 maximum error showed that the model predicted the stress-strain relationships with highly accuracy. In view of the predicted results and the

simple model consisting of input and output layer with one node, and hidden layer with five nodes, the method of stress-strain prediction for oilseeds by using artificial neural networks is both feasible and effective.

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RESEARCH OF LITCHI DISEASES DIAGNOSIS EXPERT SYSTEM BASED ON RBR AND CBR

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Abstract: To conquer the bottleneck problems existing in the traditional rule-based reasoning diseases diagnosis system, such as low reasoning efficiency and lack of flexibility, etc.. It researched the integrated case-based reasoning (CBR) and rule-based reasoning (RBR) technology, and put forward a litchi diseases diagnosis expert system (LDDES) with integrated reasoning method. The method use data mining and knowledge obtaining technology to establish knowledge base and case library. It adopt rules to instruct the retrieval and matching for CBR, and use association rule and decision trees algorithm to calculate case similarity. The experiment shows that the method can increase the system's flexibility and reasoning ability, and improve the accuracy of litchi diseases diagnosis.

Keywords: litchi, association rule, decision trees, diseases diagnosis, integrated reasoning

1. INTRODUCTION

The frequent diseases have already become one of the important elements to restrict the litchi planting in Guangdong province. It is reported inadequately that annually the incidence of litchi disease amounts to 45%, and the loss rate 25% or so, and thus the direct economic loss from the

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disease of litchi was at least 10 million more in 2007(Wang Jibo et al., 2008). In recent years, the diseases tend to be more complicated and difficult to heal.

With the development of artificial intelligence, the expert system has been applied in agriculture domain widely (Li Daoliang et al., 2002). The traditional disease diagnosis system first selects the experts' experience with the rule-based way, and then concludes a certain diagnosis rule to reason and diagnose the disease. This RBR system is characteristic of the single representation and the understandability (Fu Zetian et al., 2001). But meanwhile it comes with some disadvantages such as low reasoning efficiency, lack of flexibility, etc.. Contrasted with this, CBR seeks solutions by visiting the previous ones to similar problems in the knowledge base. Moreover, CBR can rapidly solve complicated problems, because CBR can get answers directly by retrieving index for similar cases, and it does not need to match the rules. But it is deficient to accurately express some understandably concepts; in some conditions, it fails to secure the capability to obtain solutions. In accordance with the present situation of litchi disease prevention and treatment in Guangdong province, this paper will discuss the method that can realize the efficient and accurate reasoning of the litchi disease diagnosis by combining the advantages of RBR and CBR.

2. SYSTEM ANALYSIS

2.1 Conceptual framework

Litchi disease diagnosis means that the diagnosis agent (litchi diagnosis expert), in some ways, studies and examines information from the diagnosis object (litchi), judges the health condition, figures out the corresponding reasons and treatment plans, and draws specific conclusions. The influencing elements like diagnosis agent, diagnosis object, diagnosis element, diagnosis result, diagnosis method, etc..Correlate and interact to build an organic whole. As shown in Fig.1.

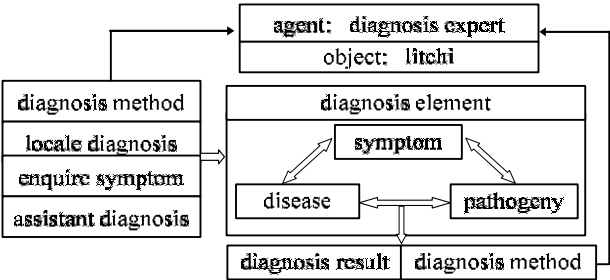


Fig.1. Conceptual framework of LDDDES

LDDES is an expert system with profound professional knowledge of litchi planting. The system applies data mining and knowledge obtaining method to gain specific knowledge of litchi planting domain, uses the artificial intelligence knowledge reasoning method to reason and study, and simulates the experts' thinking and reasoning to diagnose and cure diseases. LDDES mainly covers the following two aspects:

(1) Mining and extracting the diagnosis knowledge hiding in the cases, and get the instruction from the preceding cases for diagnosis;

(2) With aid of rules and cases, diagnosing new diseases swiftly and exactly, in order to satisfy users demand.

2.2 Data mining

Lots of fuzzy, incomplete and redundant information appear in the preceding cases, which make it necessary to clear up and filter all the data into consistency and determinacy (Rosembloom et al., 2006). Then classification algorithm is used to classify diseases and summarize diagnosis rules. Algorithms for data mining in LDDES are association rule algorithm and decision trees algorithm. The former gets diseases relativity by analyzing the frequently-used parameters: dependability, reliability and popularity; while the latter predicts diseases by matching the unknown-type diseases with the well-known ones.

With the measure of information entropy, decision trees algorithm chooses the suitable classification attribute and divides the sample data set into subsets. The equation of information entropy can be expressed as the follow (Kiang et al., 2002):

$$entropy(a) = \sum_{i=1}^2 \frac{\sum_{j=1}^c f_j}{R} \sum_{j=1}^c p(c_{ij}) \ln(p(c_{ij})) \quad (1)$$

In the equation, C means the numbers of classification attribute value; f_{ij} refers to the frequency of attribute value j appearing in the branch i; R stands for the data sample set; $p(c_{ij})$ can be expressed as:

$$p(c_{ij}) = \frac{f_{ij}}{\sum_{k=1}^c f_{ij}} \quad (2)$$

2.3 Reasoning method

CBR and RBR can be integrated in many ways, based on the analysis of litchi disease diagnosis. It adopts CBR as the main and RBR as the auxiliary for integration.

In the integrated reasoning system, Case X of CBR is described in a triad “X=<x1, x2, x3>”. Thereinto, x1 is a finite set for expository information of diseases, such as litchi’s color and weight, planting months, disease description, and description of check and diagnosis; x2 is a nonempty finite set for characteristic information of disease cases (mostly deviant values from assays being selected as characteristic information for each case); x3 is a finite set for the eliciting information of cases such as professional knowledge, treatment plans and treatment results, etc..

CBR process is mainly composed of case retrieve, case reuse, case revision and case maintenance, among which case retrieve is the key step to CBR.

The case similarity retrieve is the core process of case retrieve; it is different from the key word retrieve of common data base systems. The case situation consists of many attributes; therefore, it’s essential to define the similarity of case attributes first. The equation of similarity in LDDDES is as follow (Alonso et al., 2002):

$$Sim(V_i, V_j) = 1 - d(V_i, V_j) = 1 - d_{ij} \quad (3)$$

$$d_{ij} = |V_i - V_j| \quad (4)$$

Sim (Vi, Vj) stands for the similarity quantity between Vi and Vj, d(Vi, Vj) for the distance between Vi and Vj.

With the definition above, the calculation of similarity between cases can be carried out. The similarity between cases confined by attributes distance superposition. The frequently-used typical distance definition is:

$$d_{ij} = \sum_{i=1}^N |v_{ik} - v_{jk}| \quad (5)$$

The previous definition ordinarily treats functions of each attribute exactly alike. But factually each attribute makes different contribution to the similarity, therefore, attribute weight is demanded, and another equation instead of equation (5) is as follow:

$$d_{ij} = \sum_{k=1}^N w_k d(v_{ik}, v_{jk}) \quad (6)$$

wk is the kth attribute weight, and its definition is:

$$\sum_{k=1}^N w_k = 1 \quad (7)$$

$d(V_i, V_{jk})$ is the distance between the i th case and j th case in the k th attribute. Then the definition of similarity between two cases is:

$$Sim_{ij} = 1 - d_{ij}, d_{ij} \in [0, 1] \quad (8)$$

Equation (8) is adopted to calculate the cases similarities in LDDDES.

The attribute weight is determined by litchi planting experts. The weights in cases are equal under the default situation. The shorter the distance between cases is, the closer the similarity is. The closer the calculation similarity, the better the matching.

2.4 Implementation of reasoning

Implementation of reasoning includes the following steps:

(1) For a new case, the system firstly traverses the whole rules library, then with the help of RBR, obtains the elementary diagnosis, and meanwhile calculates the rate of each possible diagnosis results;

(2) A new CBR target case is built up by reasoning result of RBR and the expected diagnosed case;

(3) RBR reasoning result is utilized by CBR to instruct the searching and matching to seek similar cases;

(4) Cases are corrected and adjusted to get closer to the expected case.

(5) According to the retrieve results, the rules are adjusted to preserve in the rule library;

(6) Cases are preserved in the case library.

In the reasoning process, rules representing disease diagnosis knowledge are used to reinforce and improve CBR efficiency. The preservation of rules and cases makes incremental learning of system knowledge, and betters the reasoning capability.

3. DESIGN AND IMPLEMENTATION OF LDDDES

3.1 System architecture

Presently CBR systems contain a multitude of mixed modules. CHEF system supports CBR with submodules based on rules (Alonso et al., 2002); CASEY system complements mechanisms based on rules with cases (Qu Ming et al., 2004); Rissland and Skalak combine RBR and CBR to set up CABARET system. The architecture of LDDDES in the article is shown in

Fig.2. There are two layers: knowledge establishment layer and knowledge reasoning layer.

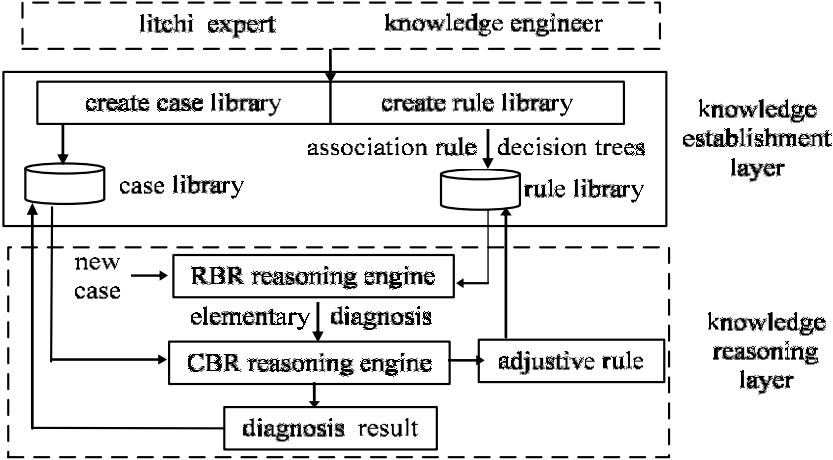


Fig.2. Architecture of LDDDES

On the knowledge establishment layer the case library is founded by a large quantity of historical typical cases summarized by litchi planting experts; the rule library is established by mining potential disease diagnosis rules from dozens of ruleless case data. On the knowledge reasoning layer the disease diagnosis result is acquired by integrated reasoning when a new case is input.

3.2 Knowledge establishment

Knowledge is shown as sufficient cases in the case library and lots of disease diagnosis rules in the rule library. Knowledge establishment is mostly finished on the establishment layer.

Case library establishment: it is founded by a large quantity of typical cases for years summarized by litchi planting experts. It' is a process ranging from preserving cases to establishing index of relevant case, thus building up a case library the reasoning system demands. The case library is the foundation of CBR.

Rules library establishment: litchi case is a set for a large volume of data in different types. The process of data mining is to use tools and algorithms to find out relations in modules and data, and to obtain potential knowledge. On the knowledge establishment layer, decision trees algorithm and association rule algorithm are used to summarize the relevant rules of disease diagnosis. By assessment and classification, the rules at last are preserved in the rule library for RBR use.

3.3 Knowledge reasoning

The reasoning process of the system is: with the adjuvant result of RBR, CBR achieves the diagnoses of target cases; with the instruction of RBR, CBR retrieves the closest case relative to the target case. The knowledge reasoning layer consists of RBR reasoning engine and CBR reasoning engine, both of which cooperate and mutually complete the task of disease diagnosis and reasoning. The reasoning steps are described as follow:

- (1) supposing case library C exist cases $c_1, c_2, \dots, c_n$;
- (2) initialize x // initializing target case x ;
- (3) $x' \leftarrow \text{RBR } x$ // RBR reasoning creating initial results and regenerating target case x' ;
- (4) $C \leftarrow x'$ // inputting target case x' to case library;
- (5) retrieving target set;
- (6) for each $c_i \in \text{target set}$ do // c_i stands for each case in C
- (7) $\text{similarity}(x', c_i)$ // calculating the similarity between x' and c_i according to similarity function;
- (8) figuring out the subsequent case of $c_i : c_{i+1}$
- (9) while (all cases in target set being found);
- (10) $t = \max(\text{similarity}(x', c_j))$ // seeking case c_j which is closest to x' ;
- (11) case adjustment and amendment;
- (12) getting reasoning result and storing new case.

4. EXPERIMENT

In order to validate the reliability of reasoning algorithm, the function of LDDDES has been implemented based on Visual Studio2005 platform. The main function module of the system including: case information input module, knowledge establishment module, integrating reasoning module and result assessment module. The core algorithm used in the system including: association rule algorithm, decision trees algorithm and similarity retrieve algorithm.

The system analyzes litchi diseases assay data recorded by Guangdong Ocean University in recent three years. The data is divided into two parts: one for data base with the purpose of data mining, the other for case library purposefully for case reasoning. In the testing process, it sampled 12 random records from 1500 cases as target cases to diagnose. The diagnosis result is focused on the following litchi disease type: Capnodium (C), Pestalotia (P), Leptosphaeria (L), Ascochyta (A). The system diagnosed the selected 12

random records and find out the similarities shown in Table 1. “expert” stands for experts’ diagnosis results; “system” stands for the diagnosis results of the LDDes; “C”, “P”, “L” and “A” stand for corresponding disease type.

Table 1. Evaluation of diagnosis result

ID	1	2	3	4	5	6	7	8	9	10	11	12
expert	C	P	C	L	L	P	P	C	A	P	P	A
system	C	P	C	L	L	P	P	C	A	P	P	A
similarity	0.89	0.95	0.87	0.98	0.92	0.91	0.94	0.83	0.94	0.98	0.92	0.91

5. CONCLUSION

According to the normal disease diagnosis process for litchi, this paper researched the case-based and rule-based reasoning technology, and put forward a diseases diagnosis system LDDes with integrated method. Besides, the theory, the architecture, and the reasoning algorithm of the system were introduced. The critical technology and the function were designed. LDDes accords with the litchi diseases diagnosis. The integrated reasoning method used in this paper not only greatly reinforce the flexibility and reasoning capability but also abate the burden of case retrieve and case library. At present, LDDes has been applied to the litchi disease diagnosis in Guangdong Province.

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A DECISION SUPPORT SYSTEM FOR DO PREDICTION BASED ON FUZZY MODEL AND NEURAL NETWORK

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Abstract: Dissolved oxygen (DO) concentration plays a very important role in fish life and aquaculture, but DO prediction is very difficult. So a decision support system for DO prediction based on fuzzy model and neural network was attempted. The paper was based on vast monitored data, every day detecting for two years, in aquaculture pond in North China for two years. This is a preliminary attempt towards a wider use of Artificial Neural Networks in the management of aquaculture water quality. It proposes a model to be used effectively in prediction of DO concentration in aquaculture. This is really a crucial task, especially during the long dry summer months. The prediction of potential risk due to low DO is also very important. This data volume was divided in the training subset comprising of 106 cases and in the testing subset containing 26 cases. The input parameters are sunlight, wind speed, temperature, water temperature, air pressure, pH value and NH-NH₃. Consequently three structural and seven dynamic factors are considered. After several and extended training-testing efforts a Modular Artificial Neural Network was determined to be the optimal one.

Keywords: DO, neural network, prediction, fuzzy model

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1. INTRODUCTION

In recent years, many fish, shrimp and shellfish death and frequent emerging of all kinds of disease had reduced the fishermen income and brought out quality unsafety due that serious aging and eutrophicated aquaculture ponds and unbalance of ecosystem of aquaculture water (Boyd et al., 1982; Madenjian et al., 1987). So water quality management has becoming the most important element for constraining the output of the fish. DO is the most important factor in aquaculture (Madenjian, 1990; Fritz, 1985; Miller, 1990). If DO concentration sustains a low or a high value for a long time, it will lead to fish's die, to know DO concentration at anytime is very essential for fisheries, it is far from the detection of DO (Hjelmfelt et al., 1993; Jan, 1997), the key is to predict DO to prevent the risk.

Literature offers applications of different approaches to predict DO concentration in aquaculture. Some of approaches are simple and empirical in nature. Others involve solutions to equations that yield time and space dependent levels of DO. Dynamic models with hydrodynamic transport modeling components involve solution of differential equations, which formulate relevant physical, chemical and biological mechanisms and interactions as ecological formulations (Babovic et al., 1997).

The results obtained, utilizing simple empirical and statistical approaches, usually do not possess high precision. On the other hand, the calibration, validation and test steps of models that have hydrodynamic components require extensive field work and calculation efforts. Development of NN approaches with high precision of estimation was considered to be effective in eliminating the arduous task of filed works and development of complex models that involve partial differential estimations. The main intentions were to minimize field work and to improve precision of estimations; most of these studies are related to primary productivity quantification in water bodies (Babovic et al., 1997; Soyupak et al., 2003).

From vast detected data, it is a complicated relation between DO and other factors in aquaculture. They have not evidently relation; neural network is feasible for these issues, but neural network is a black box, therefore, this paper combined fuzzy system and neural network (Stamou, et al., 1995; Lacroix et al., 1997; Yang et al., 1993; Guan,1996). Fuzzy system can express human experience, knowledge for computer to identify; it can also be founded some models to human feelings, language and actions; it can reasoning and deducing. Multidimensional characteristic, parallel distributed processing nature, adaptability, self-organization and self-learning can be used with fuzzy system to predict DO concentration (Wang et al., 2004; Loftus,1993; RAFI, 1992; Scott et al., 1990).

A traffic light decision system for marine finfish aquaculture sitting (Hargrave, 2002); A decision support system POND which enables

definition of an entire aquaculture facility has been developed by John Bolte (2000); And Aqua Farm is a simulation and decision support for aquaculture facility design and management planning (Ernst, 2000); fish sorting (Zion et al., 2000), and automated feeding system (Papandroulakis et al., 2002). So, it can be seen that the DSS has developed a lot in aquaculture in recent years, but the development in the aspect of pond water quality management, which is the main factor for successful aquaculture, is of a small quantity.

2. DESIGN OF ARCHITECTURAL FRAMEWORK

For n input and single output fuzzy system, the fuzzy rule is:
IF : $x_1 = A_1^j$,and $x_2 = A_2^j$, $\cdots$,and $x_n = A_n^j$,**THEN** $y = B_j$;
 $A_1^j, A_2^j, \cdots, A_n^j, B_j$ are fuzzy subset. Fuzzy subset B_j was instead at the end, i. e. :**IF** : $x_1 = A_1^j$,and $x_2 = A_2^j$, $\cdots$,and $x_n = A_n^j$,**THEN** $y = f_j(x)$; $f_j(x)$ often take as the linear combination of input parameter, i.e. $f_j(x) = c_j^1x_1 + c_j^2x_2 + \cdots + c_j^nx_n + c_j^{n+1}$

Instead of the division of input apace, the below model was adopted.
IF: $X \in R_j$,**THEN** $y = f_j(X)$ (1)

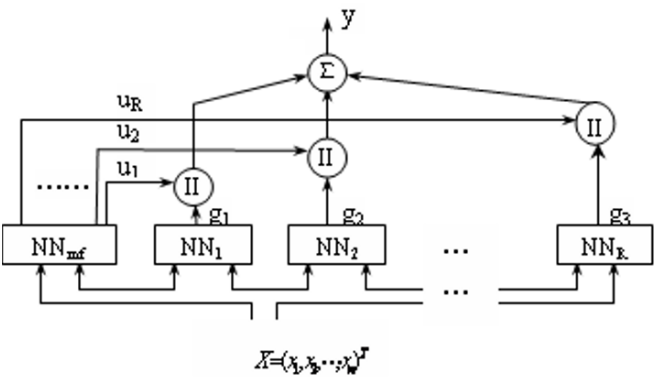


Fig.1: The architecture of fuzzy system based on neural network

Fig.1 is architecture of fuzzy system, $X = (x_1, x_2, \cdots, x_n)^T$, R_j is the partial space after division. It can be given that the grade of membership of union the input parameter. At the same time, $f_j(X)$ can be describing by neural network. So the combination the neural network and the fuzzy system,

we can obtain the fuzzy system based on neural network (Meulenberget al., 1996; Borchherding et al., 1993).

In above fuzzy system, there are R+1 of neural network, NN1~NNR describe $f_j(x)$ in the result of R rules, and NNmf gives the rule applicability, and the output of fuzzy system was determined by follow formula.

$$y = \sum_{j=1}^R u_j \cdot g_j \quad (2)$$

3. STRUCTURE AND ARITHMETIC ANALYSIS

3.1 Structure of Neural Network Model

We choose BPNN to simulate. The network includes input layer, hidden layer and output layer. For a transportation network with n nodes and m links, the number of nodes of input layer is $n^2 - n$, and that of output layer is m, and that of hidden layer is $\sqrt{m(n^2 - n)}$. For simply transportation network, number of nodes of hidden layer should be increased appropriately. Activation function is shown as follows.

$$f(x) = \frac{1}{1 + e^{-\lambda x}} \quad (3)$$

According to training cases value of input and out (x_i and t_i), they are real detection data. Then calculate output error in course of random weight and value, and transmit error converse to input layer to modify the weight and value to study. Suppose there are p group data for training, i.e. x_i^p and t_i^p , t_i^p is network expectation output, $y_i^{p_1}$ is the output value according to training, so to p group data, the average variance is shown as follows.

$$E = \sum_{p_1=1}^p \sum_{l=1}^{m-1} (t_l^{p_1} - y_l^{p_1})^2 \quad (4)$$

3.2 Arithmetic Analysis of the Neural Network

3.2.1 Initialization of the Neural Network

Let all joint weight to be a random value between -1 and 1. i.e. $w_{sq}(0) = \text{Random}(\bullet)$, sq is ij, jk, kl ; let all value is to be a random value between 0 and 1. Then input the samples to the network in fig.2.

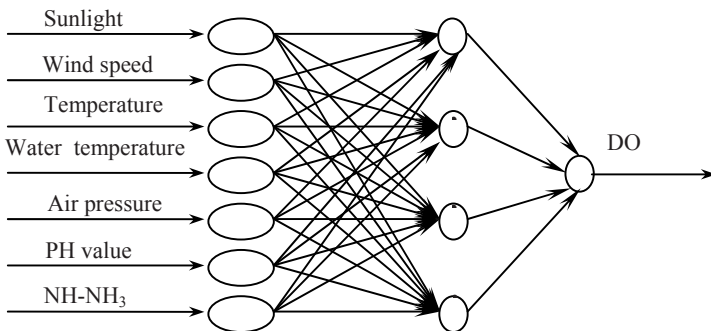


Fig.2: Neural network framework of DO prediction

3.2.2 Training of Neural Network

Provide cases (x^{p_1}, y^{p_1}) , $p_1 = 1, 2, \dots, p$ for training.

Steps 1: calculate every layer value:

$$\begin{cases} y_l = f(\sum_{k=0}^{n_2-1} w_{kl}'' x_k'' - \theta_l'') \\ f(x) = (1 - e^{-\lambda x})^{-1} \end{cases} \quad l = 0, 1, 2, \dots, m-1 \quad (5)$$

$$\begin{cases} x_k'' = f(\sum_{j=0}^{n_1-1} w_{jk}' x_j' - \theta_k') \\ f(x) = (1 - e^{-\lambda x})^{-1} \end{cases} \quad k = 0, 1, 2, \dots, n_2 - 1 \quad (6)$$

$$\begin{cases} x_j' = f(\sum_{i=0}^{n-1} w_{ij} x_i - \theta_j) \\ f(x) = (1 - e^{-\lambda x})^{-1} \end{cases} \quad j = 0, 1, 2, \dots, n_1 - 1 \quad (7)$$

In the paper, hidden layer is tow layers, the first layer has n_1 nerve cell, $x' \in R^{n_1}$, $x' = (x'_0, x'_1, \dots, x'_{n_1-1})^T$; The second layer has n_2 nerver cell, $x'' \in R^{n_2}$, $x'' = (x''_0, x''_1, \dots, x''_{n_2-1})^T$

Output layer $y \in R^m$, there are m nerve cells, $y = (y_0, y_1, \dots, y_{m-1})^T$, the joint weight between input layer and the second layer is w_{ij} , threshold is θ_j , the joint weight between the second layer and the third layer is w'_{jk} , threshold is θ'_k , the joint weight between the third layer and output layer is w''_{kl} , threshold is θ''_l .

Step 2: calculate the error of every layer

$$\delta_{kl}^{P_1} = (t_l^{P_1} - y_l^{P_1}) y_l^{P_1} (1 - y_l^{P_1}) \quad (8)$$

$$\delta_{jk}^{P_1} = \sum_{l=0}^{m-1} \delta_{kl}^{P_1} w''_{kl} x_k^{P_1} (1 - x_k^{P_1}) \quad (9)$$

$$\delta_{ij}^{P_1} = \sum_{k=0}^{n_2-1} \delta_{jk}^{P_1} w'_{jk} x_j^{P_1} (1 - x_j^{P_1}) \quad (10)$$

Step 3: modify the weight and value of every layer

$$w''_{kl}(n+1) = w''_{kl}(n) + \alpha(n) \sum_{P_1=1}^P \delta_{kl}^{P_1} x_k^{P_1} \quad (11)$$

$$\theta''_l(n+1) = \theta''_l(n) + \beta(n) \sum_{P_1=1}^P \delta_{kl}^{P_1} \quad (12)$$

$$w'_{jk}(n+1) = w'_{jk}(n) + \alpha(n) \sum_{P_1=1}^P \delta_{jk}^{P_1} x_j^{P_1} \quad (13)$$

$$\theta'_k(n+1) = \theta'_k(n) + \beta(n) \sum_{P_1=1}^P \delta_{jk}^{P_1} \quad (14)$$

$$w_{ij}(n+1) = w_{ij}(n) + \alpha(n) \sum_{P_1=1}^P \delta_{ik}^{P_1} x_j^{P_1} \quad (15)$$

$$\theta_j(n+1) = \theta_j(n) + \beta(n) \sum_{P_1=1}^P \delta_{ik}^{P_1} \quad (16)$$

Step 4: according to the joint weight after modified, redo the step 1, step 2 and step 3, until for every P_1 and l , there is:

$$|t_l^{P_1} - y_l^{P_1}| < \varepsilon \quad (17)$$

Then training is over. In above formula: n —iterative time; $\alpha(n)$ and $\beta(n)$ —respectively are joint weight and study rate of threshold, commonly think them as ($0 < \alpha(n), \beta(n) > 0$); λ —shape function of Sigmoid

function ,in the paper, $\lambda =0.1$; y_i —the output value of output layer y network study; $t_i^{P_1}$ —the expectation output of the output layer y ; ε — according to the users' precision require, choose a decimal fraction that no less than zero, in the paper, $\varepsilon =0.0028$.

4. FOUNDATION OF DO PREDICTION MODEL

4.1 Grouping for Data

For the veracity of the training network and validating prediction, the input data (x_i, y_i) was divided into two parts, one part is for training network, the other part is for evaluation the output result of the model. The paper adopts 106 group data as training data, and 43 group data as evaluation data.

4.2 Foundation of the Fuzzy Rule

The number of the fuzzy rule m was confirmed by fuzzy clustering, one rule will be adapt for one group data, suppose there are R group, then the number of rule is R . The precision and complexity must be considered, so the paper adopted distance square summation D in K -means, the number of group was confirmed by the decrease of D when a group increasing.

For the above 106 data, it would be standardized with the follow methods:

$$x = \frac{x' - x'_{\min}}{x'_{\max} - x'_{\min}} \tag{18}$$

x —data after standardization; x' —original data; $x'_{\min}$ —the minimum of the original data; $x'_{\max}$ —the maximum of the original data.

Now the data was in the scope of 0 and 1, it would be propitious to the training of neural network. And then the law absolute subtrahend was used for number grouping. The result of grouping is as [table1](#).

Table 1. The result of grouping

Group number		The number of samples for training		
1	1	2	3	47-106
2	4-46			

4.3 Training of NNmf network

NNmf was made up of n input variable and R output variable. The study sample was defined as the follows: suppose that x_i in the study sample was clustered to the S group, then:

$$w_j^i = \begin{cases} ON & j = S \\ OFF & j \neq S \end{cases} \quad j = 1, 2, \dots, R \quad (19)$$

In the fomula: On=0.9, Off=0.1

4.4 The Design of Input Layer and Output Layer and Other Parameters

The input layer is sunlight, wind speed, temperature, water temperature, air pressure, pH value and NH-NH₃. These factors are related to DO concentration according to the experts' research. Output layer is DO only. The paper chooses three layer backwards BP network model using for reference other researchers in this domain.

The cell number of hidden layer is a complex issue in neural network. In this paper, 14 cell numbers was chosen as double of ell number of the input layer, after training, if it was not successful, tow cell numbers would be added, repeat the above until it successes. Consequently three structural and seven dynamic factors are considered. [Fig.2](#) is framework of DO prediction.

5. RESULTS

The pond simulation can be established to simulate the existing complicated pond ecosystem dynamically. And interactive modeling in real-time is the key advantage of this part.

From the systematic point of view, the pond ecosystem is comprised of a series of dynamic, nonlinear and variably interacted factors, which shows the characteristic of a fuzzy system. Accordingly, the theory of system dynamics and improved neural network were used to analysis and simulate the factors affected the pond ecosystem. Subsequently, the forecasting models, which can provide time series analysis and a substantially sophisticated view of pond ecosystem dynamics, were established to simulate DO.

Resulting from collecting real-time data from the databases and computing by the forecasting models, the trending of the simulated process will be displayed in trend curves on the computer screen. Therefore, the manager can acquire needed trending information of the key factors controlling the pond ecosystem.

The simulated results turned out that the average error was 3.7%, indicating that the models accorded with the prediction demand. Fig.3 shows the DO real-time simulated trend curves interface. Fig.4 shows the prediction interface of DO.

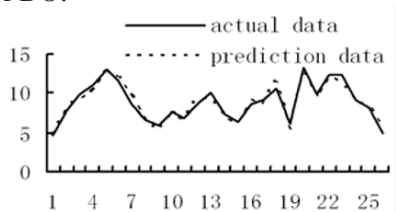


Fig.3: Comparison of real value and prediction value



Fig.4 Forecasting interface of DO

6. CONCLUSION

From Fig.3, it is known that prediction value is very close to actual value. Average error between actual data and prediction data is 0.538(mg/l), it is receivable for aquaculture. This can prove that DO prediction fuzzy system model based on neural network can be retrieved successfully.

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QPAIS: A WEB-BASED EXPERT SYSTEM FOR ASSISTED IDENTIFICATION OF QUARANTINE STORED INSECT PESTS

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Abstract: Stored insect pests can seriously depredate stored products causing worldwide economic losses. Pests enter countries traveling with transported goods. Inspection and Quarantine activities are essential to prevent the invasion and spread of pests. Identification of quarantine stored insect pests is an important component of the China's Inspection and Quarantine procedure, and it is necessary not only to identify whether the species captured is an invasive species, but determine control procedures for stored insect pests. With the development of information technologies, many expert systems that aid in the identification of agricultural pests have been developed. Expert systems for the identification of quarantine stored insect pests are rare and are mainly developed for stand-alone PCs. This paper describes the development of a web-based expert system for identification of quarantine stored insect pests as part of the China 11th Five-Year National Scientific and Technological Support Project (115 Project). Based on user needs, textual knowledge and images were gathered from the literature and expert interviews. ASP.NET, C# and SQL language were used to program the system. Improvement of identification efficiency and flexibility was achieved using a new inference method called characteristic-select-based spatial distance method. The expert system can assist identifying 150 species of quarantine stored insect pests and provide detailed information for each species. The expert system has also been evaluated using two steps: system testing and identification testing. With a

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85% rate of correct identification and high efficiency, the system evaluation shows that this expert system can be used in identification work of quarantine stored insect pests.

Keywords: expert systems, quarantine stored insect pests, identification, stored products

1. INTRODUCTION

Stored products play an important role in every country because they ensure a food supply and strengthen the stability of national economies. Generally, stored products contain grain, oil, medicinal materials, tobacco, fur, books, file documents, etc. They are usually preserved in environments which include storehouses, workshops, warehouses, libraries, etc. Stored pests are those that live in these environments and include insect pests, mites, rodents, etc. Stored pests have the ability to adapt themselves to stored product environments and can cause severe damages to every kind of stored product by feeding and contaminating them. Research from USDA (United States Department of Agriculture) showed that stored pests caused 2.3 billion dollars in losses during the storing and processing of agricultural products in 1960s (Yin et al., 2002). In China, during the annual storage period in 1980s, the loss caused by stored pests in grain oil was about 10%, losses in Chinese traditional medicine materials were about 70% (Li et al., 2000). In order to reduce losses against stored pests, about 3 billion kilograms pesticides were used worldwide, which contributes to environmental pollution (Pinentel, 1991). Stored pests are now being widely researched to better manage them across the world because of their astounding ability to destroy products and their economic importance. Although some success has been attained in recent years using a variety of preventative methods including physical prevention, chemical prevention and biological prevention, it is still a long-term and complicated task to control stored pests, especially preventing the spread of stored pests from one country/place to other countries/places. With more and more international trade and communication, it becomes increasingly likely that stored pests are able to move with goods. Inspection and Quarantine work is a vital procedure for every country in order to control the spread of domestic stored pests and to prevent the invasion of foreign stored pests, especially quarantine stored pests. There are 533 stored pest species known in the world and 383 of these exist in China, stored insect pests account for the majority of them (Yin et al., 2002). In China, only a few parts of stored insect pests are quarantine stored insect pests (Xu, 1994), and are mainly in

the families *Dermestidae* and *Bruchidae*. Identification is an important step in the process of Inspection and Quarantine work to identify species captured. Traditionally in China, species determination by personnel trained in insect identification was the norm, but the requirements of Inspection and Quarantine work under the new international era, the lack of taxonomic specialists, low efficiency, and other factors necessitate other approaches. The rapid development and the wide use of information technologies in different fields present the opportunity to make insect identification more efficient.

An expert system, a kind of intelligent computer program, uses knowledge and inference to solve problems that are difficult enough to require human domain experts. Expert systems have been developed for identification applications in every field of agriculture, involving insect pests, weeds, poultry diseases, etc. (e.g. Liu et al., 2002; Tang, 1999; Feng et al., 2007; Travis et al., 1992). In the identification of stored insect pests, only a few expert systems have been reported (e.g. Li et al., 2006; Li et al., 2001). Li Kaibing et al. (2006) developed a *Scolytidae* Identification System, which is a multimedia expert system for identification of *Scolytidae* stored insect pests involved in China Inspection and Quarantine work, this expert system is based on Taxokeys that is an insect classification platform (Gao, 2003).

All of the existing expert systems for identification of stored insect pests only refer to a few taxa within the quarantine stored insect pests and were developed for stand-alone PCs. The inference method of identification used in these expert systems is the traditional key-based binary tree search method which takes users much time and is less flexible. With the rapid development of Internet technologies, building a web-based expert system with a more flexible and highly efficient inference method for identification of all quarantine stored insect pests is essential to China's inspection and quarantine work.

A web-based expert system for identification of quarantine stored insect pests, called QPAIS (Quarantine Pests of Stored Products Assistant Identification System), has been developed by the Plant Quarantine Laboratory at China Agricultural University. It is an outcome of the China 11th Five-Year National Scientific and Technological Support Project (115 Project). This web-based intelligent system contains a large amount of detailed textual information and images of about 150 quarantine stored insect pest species. An array of inference knowledge with a new inference method for identification was also included in this system. The inference method is a characteristic-select-based spatial distance method with high efficiency and high accuracy. The expert system has been tested and will be used in China's Inspection and Quarantine work. In addition, the system can also be used in educational training.

2. DOMAIN BACKGROUND

2.1 Brief introduction of taxonomy

Quarantine stored insect pests in China mainly refer to species in the *Dermestidae* and *Bruchidae*, which belong to the beetles (*Coleoptera*). These species have a common life cycle, which consists of four life stages including egg, larva, pupa and adult. The adults of these beetles have small, ovoid bodies covered with scales or hairs of different colors. The main parts of the adult body include the head, thorax and abdomen. Also common to the adult are a pair of antennae of varying shapes, three pairs of legs, two pairs of wings, with first pair hardened into elytra.

2.2 General process of identification

Compared with the other three life stages, the adult is easier to identify because of distinctive characteristics, such as the shape of antennae, different color hair zones on the body and elytra, the shape of pronotum, etc. Species are classified into a number of groups based on common characteristics, all groups have a hierarchical relationship with each other. For example, the species *Dermestes dimidiatus* belongs to the genus *Dermestes* which belongs to the family *Dermestidae*. There must be at least one different characteristic between any two species which can be used in identification.

In the traditional identification process of quarantine stored insect pests, the first step is to observe all the characteristics of an unknown adult, usually by eyes or with a microscope. The second step is to determine the species by comparing all the observations with knowledge including text and images from books or identification experience. Sometimes, these two steps are simultaneous.

3. USERS' NEEDS

According to interception records of quarantine stored insect pests from China inspection offices at ports during the past decade, transportation of goods is the major avenue for pests to spread with from one country to another. Identification work is vital to determine whether a species captured is a foreign invasive species or a domestic species, and then help to make a decision about the disposal of the goods containing pests.

In order to meet the requirements of China's Inspection and Quarantine work under the new international era, an inquiry was conducted by China National Academy of Inspection and Quarantine (CAIQ) to find out the practical needs of China's inspection offices at the ports. The results show that these offices have many needs:

1. Lack of classification experts. The identification work can be accomplished by classification experts who possess the proper knowledge and abundant practical identification experience. China is a large country and has many port inspection offices. People working in these offices have only basic knowledge of taxonomy and still need to consult taxonomy experts when a species which is not familiar to them is captured. As the number of taxonomy experts in China is limited, the identification shortfalls at inspection offices cannot be resolved.

2. Long time needed. If a classification expert is not available, identification work often requires inexperienced port personnel to spend much time consulting literature in order to make identifications.

3. Lack of systematic data. Detailed information, such as taxonomic position, quarantine status, classification characteristics, biology characteristics, geographic distributions, etc., is difficult to acquire. People working in port inspection offices still need to gather the information from many reference books or the internet.

A web-based assistant identification system, which can be used in China's Inspection and Quarantine offices will help resolve the problems mentioned above.

4. KNOWLEDGE ACQUISITION

A critical aspect of building an expert system is formulating the scope of the problem and gleaning from the source expert the domain information needed to solve the problem ([Gonzalez-Andujar, 2006](#)). This aspect can be achieved through knowledge acquisition, which is an important process and has always been considered a bottleneck during the development period of expert systems. This bottleneck is mainly caused by communication difficulties between the knowledge engineer (KE) and the domain expert, the inability of the expert to describe his/her expertise, and the inability of the KE to understand and codify the expertise ([Liebowitz et al., 1996](#); [Li et al., 2002](#)). In the present system, two approaches have been adopted to achieve knowledge acquisition.

4.1 Literature reference

Textual information (e.g. species’ morphological characteristics, biology, geographic distribution, etc.) and images of 150 species of quarantine stored insect pests in *Dermestidae* and *Bruchuidae* were acquired from literature such as textbooks, primary and secondary literature, papers, etc. We also collected some images from the China National Academy of Inspection and Quarantine (CAIQ). All these quarantine stored insect pest species, which account for bulk of stored pests, were commonly found in international trade all around the world.

4.2 Experts interviews

Through years of experience, taxonomy experts have developed a body of knowledge and classification experience which they can use to make correct identifications (Li et al., 2002). The famous taxonomy expert of stored insect pests from China National Academy of Inspection and Quarantine (CAIQ) took part in knowledge acquisition.

Table 1. *Dermestes* species considered in QPAIS with Abdomen hair Identification characteristic and its choices

Dermestes species	Identification characteristics		
	Abdomen hair		
Latin name	Having thickly white or light yellow hairs which cover abdomen	Having thinly light yellow or dark color hairs which don't cover abdomen	Not clear
Dermestes dimidiatus	×		×
Dermestes elegans	×		×
Dermestes marmoratus	×		×
Dermestes coronatus	×		×
Dermestes maculates	×		×
Dermestes carnivorus	×		×
Dermestes frischii	×		×
Dermestes coarctatus	×		×
Dermestes sibiricus	×		×
Dermestes laniarius	×		×
Dermestes murinus	×		×
Dermestes undulates	×		×
Dermestes tessellatocollis	×		×
Dermestes lardarius		×	×
Dermestes vorax		×	×
Dermestes ater		×	×
Dermestes leechi		×	×
Dermestes freudei		×	×
Dermestes nidum		×	×
Dermestes haemorrhoidalis		×	×
Dermestes peruvianus		×	×

The taxonomy expert picked related identification characteristics most frequently used in identification work in different groups (e.g. *Coleoptera*, *Dermestidae*, *Bruchidae*, etc.), each identification characteristic includes some characteristic choices. The taxonomy expert also added a ‘not clear’ option to every characteristic as the final choice to accommodate absent or unclear characteristics of samples. For instance, [Table1](#). shows 16 characteristics, including abdomen hair, vaginal hair color, vaginal hair length, etc, for identifying species in *Dermestes* which contains 21 *Dermestes* species. The abdominal hair characteristic has 3 characteristic choices, two of which can be chosen to classify 21 *Dermestes* species into two smaller groups, the third one is ‘not clear’ which has no classifying function. Also, each characteristic choice was given a mark value which was defined as the degree of relatedness between characteristics and specific species. Mark values can range from 0-100 and are based on expert opinions. [Table2](#). contains an example of three characteristic choices and related mark values of the scutellum. ‘Mahogany hair on the scutellum’ is the characteristic only to *Dermestes lanarius* but not to others in *Dermestes*, so the mark value of mahogany hair on the scutellum is 100.

Table 2. Characteristic choices of scutellum with mark values in *Dermestes*

Identification characters	
Scutellum	Mark Value
Characteristic choices	
Mahogany hair on the scutellum	100
Yellow hairs on the scutellum	100
Not clear	0

5.

QPAIS EXPERT SYSTEM DESIGN AND
DEVELOPMENT

QPAIS expert system consists of a user information database, a stored insect pest information database, a knowledge database, an inference engine and a user interface. The structure is represented in [Fig.1](#).

5.1

Development software selection

QPAIS was designed to run on the internet. Its development was based on the use of internet techniques and SQL programming languages. HTML (Hypertext Markup Language), Java Script, C# and ASP.NET were used in the programming. Other software included MS SQL Server 2000, Windows XP, IIS 6.0, Photoshop 7.0 and Flash 7.0.

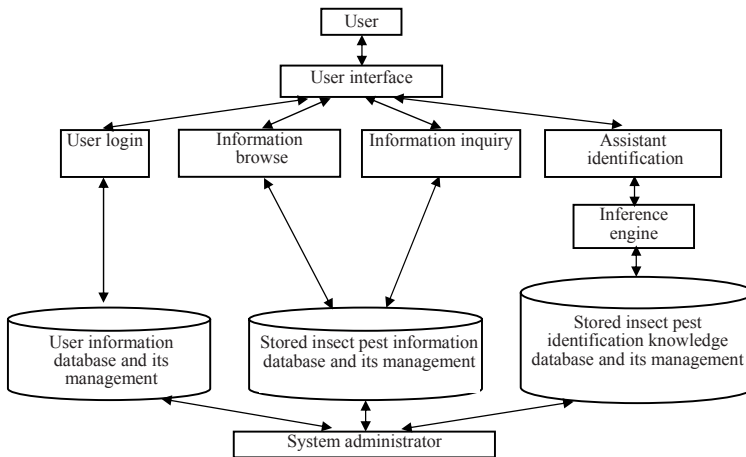


Fig.1: System structure of QPAIS

5.2 Databases

The server database played a very important role in developing QPAIS. It was used to sort all the information and knowledge which was needed to actualize every function of the expert system. In QPAIS, there are three databases including a user information database, a basic information database and an identification knowledge database. They were all designed using MS SQL Server 2000.

The user information database contains the users' name, password, rights, etc. This makes it easier for system administrators to manage users and authorize the access to different functions. The basic information database includes detailed textual information of quarantine stored insect pests, including Chinese names, scientific names, taxonomic position, quarantine status, figure descriptions, biological characteristics, geographic distributions, etc. Images related to species were also included in the basic information database. In the identification knowledge database, identification characteristics, characteristic descriptions and related mark values gathered from taxonomy experts were stored.

5.3 Inference process

The SQL language was used to operate the identification knowledge database and implement the inference process in QPAIS. The inference

process uses characteristic-select-based spatial distance method and is shown in Fig.2.

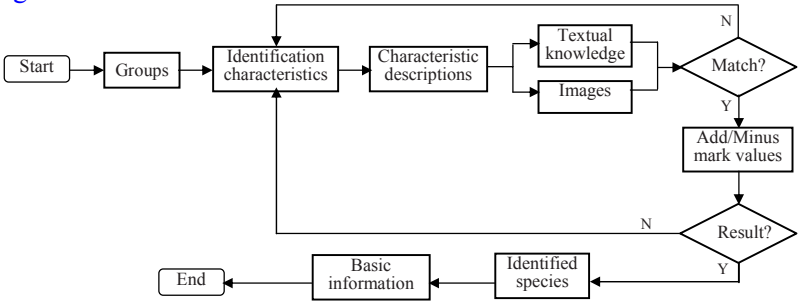


Fig.2: QPAIS inference process

For example, for an unknown species, the process starts by determining which group this species should belong to. If this species can be confirmed as a member of *Dermestes*, the system will display 16 identification characteristics. Each characteristic can be chosen to show related characteristic choices. When choosing the ‘scutellum’ characteristic, the system will show three characteristic choices with related images. If the ‘Mahogany hair on the scutellum’ choice, which is the key characteristic only to *Dermestes lanarius*, is chosen, *Dermestes lanarius* will be added to the result list with a mark value of +100, each of the other 20 species in *Dermestes* will get a -100 mark value because they do not have that characteristic. If the ‘Abdomenal hair’ characteristic is chosen as well, the system will list three corresponding characteristic choices. If ‘Having thickly white or light yellow hairs which cover abdomen’ is chosen, 13 species including *Dermestes lanarius* will be assigned +20 mark values while the other 8 species will be assigned -20. After two selections, *Dermestes lanarius* has a total mark value of +120 (100+20), 12 species having ‘Having thickly white or light yellow hairs which cover abdomen’ characteristic respectively get -80 mark values (-100+20), other 8 species respectively have -120 mark values (-100-20) as their final score. The final result list will show species having scores bigger than 0 from high to low, obviously, *Dermestes lanarius* with 120 mark values is the only one species in the result list. Then *Dermestes lanarius* can be regarded as the name of the species to be identified.

If the species cannot be confirmed as the member of a specific genus, the system will provide family identification characteristics and related characteristic choices. The result list with mark values will show *Dermestidae* or *Bruchidae* as the top item that this species should belong to. After this step, the species can be identified as the member of certain genus

in *Dermestidae* or *Bruchuidae* by choosing related genus identification characteristics.

5.4 Users interface

Users find it easy to operate the multimedia interface. There are abundant combinations of textual information and images in the interfaces. Users have three main options: information browsing, information inquiry, identification assistant. On the ‘browsing information’ page, the system displays a list of quarantine stored insect pests and the user can inspect detailed information related to a specific species after choosing its ‘browse’ link. If the user clicks the option ‘information inquiry’, the system provides an array of inquiry textboxes for users to input keywords to inquire about a specific species.

As shown in Fig.3, the ‘identification assistant’ page firstly offers a number of groups (e.g. *Dermestidae*, *Bruchuidae*, etc.) for selecting. If one of the groups is selected, the system will list related identification characteristics and characteristic choices for users to choose, all characteristic choices are combined with thumbnail sized images which can be expanded to larger ones by clicking. Fig.4 shows the identification characteristics and characteristic choices. Finally, the system shows the pest species at the top of a list which contains possible quarantine stored insect pests with different scores from high to low. Users can further check the detailed information of the identified species by clicking on linkbutton ‘browse’, which is displayed in Fig.5. The system has a record of every step in the identification process and allows users to jump back to previous steps to make another choice.



Fig.3: A screen shot for user interface on group selection



Fig.4: An example of an identification interface used to identify a species belonging to *Dermestes* with thumbnail sized images which can be expanded to larger ones by clicking



Fig.5: An example of an identification outcome interface with link button which can be clicked on to browse the detailed information of the identified species

6. SYSTEM EVALUATION

System evaluation is a process to ensure expert systems can work correctly and meet the requirements as designed. System evaluation of QPAIS contains two steps: the system testing and the identification testing. In the system testing step, function debugging, logic testing and rule checking were carried out by system developers as well as testing participants who include two programmers from China National Academy of Inspection and Quarantine (CAIQ) and 15 graduate students from Plant Quarantine Laboratory at China Agricultural University. Every function was tested for hundreds of times until it was confirmed to have no errors. Every error found was recorded for system developers to further debug.

The identification testing is a complex step which needs the taxonomic knowledge and identification experience of taxonomy experts. The taxonomy expert from China National Academy of Inspection and Quarantine (CAIQ) was responsible for this step work. A total of 150 quarantine stored insect pests were used to test the correctness of identification results. After debugging of characteristics, choices and related mark values specified by the taxonomy expert, QPAIS identification system was able to identify 85% of the cases correctly. The erroneous identifications were the consequence of misidentifications of a species and some similar species.

With the information gathered from the system evaluation, QPAIS was further improved.

7. CONCLUSIONS AND FUTURE DEVELOPMENTS

The aim of developing QPAIS was to help identify quarantine stored insect pests with high efficiency in China's Inspection and Quarantine work, as well as provided educational value. The taxonomy experts and students who used this system to identify certain species had a common opinion that QPAIS really helps improve the identifications of quarantine stored insect pests with high accuracies, and it can be used in the port inspection offices.

This system contains detailed information about 150 stored insect pest species that are commonly found in international trade and stored environments. With a large amount of textual knowledge and related images, it is easy to identify species. QPAIS is different from traditional key-based binary tree methods used in identification expert systems. QPAIS uses a characteristic-select-based method, which allows users to get the identification result in a short time just by selecting several identification

characteristic choices. QPAIS was developed to run on the internet, which is convenient for users throughout the world

Based on the records from the system evaluations, further developments are under considerations in order to make the system more helpful. This system is a prototype system and contains 150 quarantine stored insect pest species at present, to better meet the requirements of quarantine and management work, more species should be added. With the rapid development of Artificial Neural Network (ANN) in every kind of field, we are planning to refine the identification method toward ANN in the future, though it is similar to the identification method already used in QPAIS.

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RESEARCH AND IMPLEMENT OF MAIZE VARIETY PROMOTION DECISION SUPPORT SYSTEM BASED ON WEBGIS

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Abstract: In China, maize is a main cereal crop. Actually maize has a huge number of varieties which are also updating day by day. However, the seed enterprises frequently don't seriously consider the suitability of the varieties but promoting blindly, leading to the loss of both enterprises and farmers. This study focuses on the design and development of a network platform which can put forward promotion proposal of maize varieties. This platform is based on Visual Studio 2005 + SuperMap IS. NET 2008 + SQL Server 2000, and considers seed enterprises as the main target. Furthermore, it integrates varieties' suitability evaluation model and combination model which are also very helpful to the promoting of maize variety.

This system analyzes the specific requirements of users. It is integrated with the existing suitability evaluation model and combination model. With GIS, it sufficiently caters for their practice requirements and is easy-to-use, and can provide users support for decision-making in promoting or introducing varieties. At the same time it provides information of maize variety and regional planting environmental characteristics.

Keywords: maize varieties, promote application, WebGIS, decision support system

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1. INTRODUCTION

1.1 Background

Maize is one of main crops in china. With the development of biotechnology, variety of maize is increasing, which enrich the maize market in china. At the same time, the spread and introduction of varieties become a problem(Yu Xianqiang et al. 2007). This study tries to design a web-based application system which gives support to farmers when they are making decisions in the spread of varieties. This system considers Seed Enterprise as the main target consumer, and aims to satisfy all their needs sufficiently.

1.2 The purpose and content of study

This paper, aiming to promote the maize variety effectively, studies on how to develop a network system, which is based on WebGIS and integrated with the existing suitability evaluation model and combination model. Settled the promotion staff of enterprises as the target user of the system and county as the element studied, the system can provide users promotion proposals and query function of individual regional trial data of maize variety and the basic environment information.

This paper studies on how to use WebGIS to design and actualize a network application system, aiming to provide visual and telling support of promotion and serviceable function that interactive querying of attribution and graphics for basic geographic information.

2. SYSTEM ANALYSIS

2.1 Target user analysis

According to business content, system users can be divided in to following categories:

Seed Enterprise

Integrated seed enterprise: Integrated firm integrates variety selection, seed breeding and selling. Businesses create their own varieties, brands, and then sell them to consumers by retailing network. Capital needed for enrollment of integration seed enterprise is above 5,000,000RMB usually. There are nearly 500 maize variety firms in china(Tang Qilin et al. 2008). Those companies focus on where the seeds could be sold.

Seed Retailers: Most of these firms are seed agents which in the county or lower district. The number of these kinds of firms is large (nearly 5 in each county), as there are more than 10,000 in all in china. What they concern most is whether the maize variety they sell is suitable for the area.

Seed Management Institution

Seed administration management institution

These institutions include seed control station and crop farming management departments. There are nearly 2,800 institutions in china currently. Seed control station need to supervise the quality of the seed and make sure the seed variety have passed the examination. As a result, they concern with the maize variety information, trial results, and approval circumstances.

Agro-technical institution

Agro-technical station is the department which involves with seeds in the Agro-technical institution. Agro-technical station has the responsibility to recommend proper varieties which are suitable to be grown locally to the Seed administration institution(Li Enpu et al. 2005). The varieties which be recommended by Agro-technical station have the good chance to be local good subsidy varieties. These users focus on what varieties are suitable to be grown in local circumstance.

Consequently, the system takes the integrated enterprise as the main target user, and the seed retailers, seed administration institution, agro-technical institution are the second-class target users.

2.2 Overall demand of system

Previous research on the maize variety promotion application system is focus on the query of feature library, while the research on the decision-making function is rarely. Actually what needed by users is decision-making supporting information that based on the reliable basic information. How to help users to query basic data more efficiently and providing decision-making assistant are the key of maize variety application and popularity.

Key of the research on this system is how to give users the most efficient maize variety support information by integrating with GIS, including information of varieties, region circumstance information, suitability evaluation project, variety-matching plan, and so on. In addition to this, the research also designs other reasonable functions, provides a convenient, suitable and layout friendly support tools to users.

3. SYSTEM DESIGN AND ACHIEVEMENT

3.1 Overall system designs

Maize Variety Promotion Decision Support System is constituted by four parts: feature library query, theme query, popularizing analyzing tool and popularizing plan. System function structure can be found in figure 1.

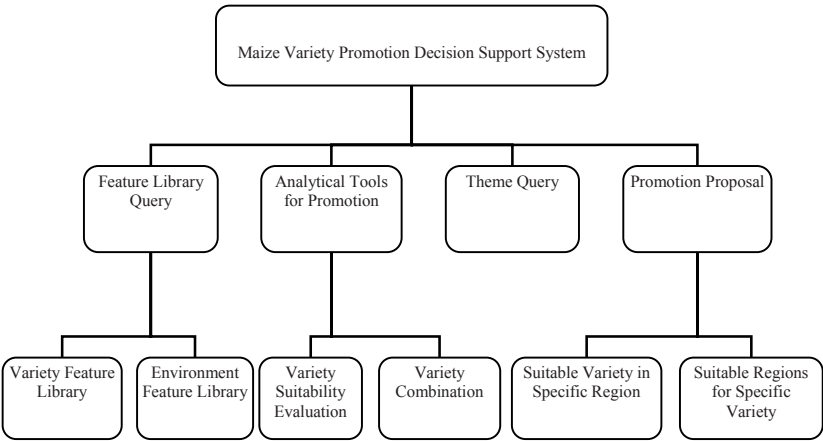


Fig. 1 Structure of Maize Variety Promotion Decision Support System

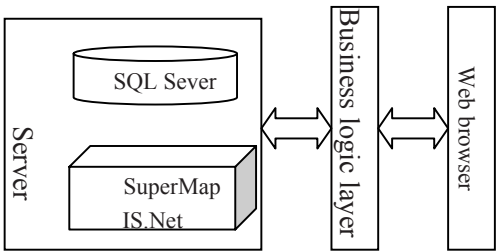


Fig. 2 Overall structure framework

3.2 Overall technology framework

Overall structure framework can be divided into 3 parts, as figure 2: After the Web browser sends request to operation logic layer, operation logic layer ask data or map data from database or SuperMap IS.NET according to the requests sent. And then it disposes the data in the operation logic layer, finally sends the results back to the Web browser.

3.3 Layout design

First page of the system is constituted by 4 elements: logo, menu bar, system introduction, and map display. Menu bar provides all the functional options. The system introduction part will turn into operation area or introduction of the module when it enters corresponding functional module. Map display part is the main area of the result information displaying. As a result, it possesses much of the total area.

3.4 Functional design and achievement

This system has four main arrangements: feature library query, theme query, analytical tools for promotion and promotion proposal. Query of feature data can help users know spread plan clearly. Theme query provides users with distributing status of nationwide relational characters of both crop level and variety level. If users do not satisfy with the plan, they can utilize analyzing tool to resolve problems according to their specific needs.

3.4.1 Feature library query

Variety Feature Library

Variety feature library query provides query about variety basic information and individual regional trial data. Users can define specific conditions to inquire about maize variety information. In addition to this, variety feature library also provide examination information of varieties to seed station users to satisfy their needs.

Environment Feature Library

Main user of this library is integrated seed enterprise and breeding enterprise. This system provides users with the basic environment information in two big maize planting districts—North East and Huang-Huai-Hai of China.

3.4.2 Theme query

This module displays all result figures for users to query. For an instance, maize dominant district layout figure.

3.4.3 Promotion proposal

The system designed this module in order to help users to know which variety suits for the specific region most, or the suitable degree distribution

of specific variety in a big region. By using this module, users can get the final spread support information without fussy operation processes.

Suitable Variety in Specific Region

Seed Retailers and Agro-technical spreading stations are the main users who query suitable varieties in specific region. By using this function, users can realize which variety is most suitable for the specific region. The total flow has 4 processes: see figure 3.

- A. select the region interested;
- B. map orientation: Enhance user’s perceptual knowledge to specific region;
- C. display simple information about the suitable variety in the specific region: usually give the top ten most suitable varieties, convenience for users to query;
- D. link with other related information: some users may not satisfy with the simple information: They want to know the suitable status of all the varieties. This linkage can give users more details. Furthermore, as seed retailers and Agro-technological stations are the main users for this module, they want know more about how to arrange different varieties in groups to increase yield. In this part, arranging plan for the region can be found out.



Fig. 3 Promotion proposal-- suitable variety in specific region

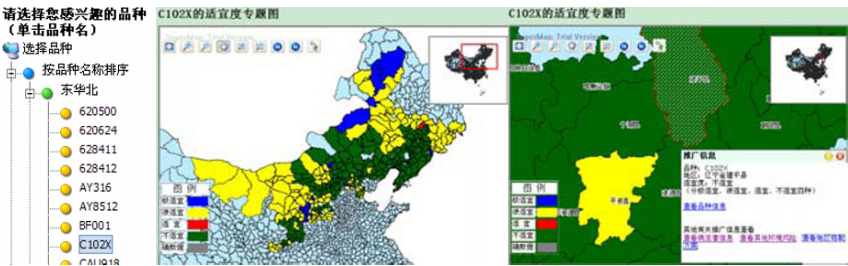


Fig. 4 Promotion proposal-- suitable regions for specific variety

Suitable Regions for Specific Variety

Main users who query the suitable region for specific variety are integrated seed enterprises and breeding enterprises. Users can know certain specific variety’s suitable degree distribution status in a big district. This flow has 4 steps: see as figure 4.

A. select variety interested in: as there are so many various varieties, the system have designed 3 different method to display those varieties—order it according to variety name, yield per unit or procreating period; besides, each ordering method has its corresponding specific regions;

B. theme figure for suitability degree;

C. select region: users can query variety suitable degree information of the interested region in the theme figure;

D. specialized thematic maps of degree of suitability(DS): a specialized thematic map is generated real-time according to the selected variety and the corresponding examination region;

E. link with other related information: variety suitable degree is depend upon plant diseases, insect pests, and growing environment analysis, so it is necessary to offer information about plant diseases, insect pests, and environment information. Additionally, because main users for this module is integrated seed enterprise and breeding enterprise, they want know whether the variety is suitable for arranging in groups to grow in this region. In this linkage, users can check the arranging plans in the region.

3.4.4 Analytical tools for promotion

Variety Suitability Evaluation

Suitability evaluation means analyzing a new maize variety's suitability degree in a specific region, finishing qualitative, quantitative, and orientation evaluation for a specific maize variety in an idiographic area ([Smith et al. 2001](#)).

Variety Combination

Maize variety combination is combining various suitable varieties together effectively to balance the yield and risk of maize production.

4. KEY TECHNOLOGY IN PROGRAMMING

4.1 Dynamically loading data of treeview

The selectable data of regions and varieties is plenty. To facilitate the users to select, TreeView which is hierarchical is chosen to load the data. Nevertheless, in case the data is completely loaded when the page is loading, the response duration of page is too long and user should pay much time to wait. In addition, TreeView provided by ASP.NET has several defects, such as slow response speed, complex operation, and ugly guise.

Dynamically loading data of TreeView is adopted. In this case, not only the response is accelerated, but also the flexibility of connection with dataset is improved. The introduction of the new control, `about_ASPTreeView_2_.NET`, brings high response speed and convenient operation.

4.2 Real-time generating specialized thematic maps

SuperMap IS.NET, the platforms system adopts, can generate specialized thematic maps with property fields included in the layers. But the property data, which system needs generate thematic maps, is stored in the SQL Sever. Furthermore, SuperMap doesn't provide the interface, which allows joining the dataset.

If the layer contains the property fields (such as DS) which need to be generated thematic maps, SuperMap will assign with different colors according the values of DS as long as DS is set as the expression of the thematic maps. However, the data isn't contained in the attribution of layers. Observing the attribution of layers and the dataset, a same field, CountyID (Standard Code of County), is found between the layers and the dataset. Set it as the expression of thematic maps, then assign the CountyID searched from the dataset the corresponding color, which is decided by the corresponding DS stored in the dataset. As a circulation, the same values of DS are assigned the same color. Namely the mutual field, CountyID, joins the layers and the SQL Sever. As a result, the function of real-time generating specialized thematic maps is accomplished.

4.3 Stored procedure

There are many interactions with SQL Sever in programming, including data acquisition from several tables and even acquiring operational result of data storing in the dataset. Achievement in the program must lead to enormous code and low efficiency.

System uses Stored Procedure. Stored Procedure can not only settle the problem that have listed, but also greatly ameliorate the performance of SQL. In addition, Stored Procedure runs at sever, which can reduce the pressure of the custom and consequently decrease the network traffic (Liu Xin 2008, Lv Jing et al. 2001, Wen Rui et al. 2007, Zhang Yueting et al. 2007).

5. CONCLUSION

This system is integrated with the existing suitability evaluation model and combination model. With GIS, it sufficiently caters for users' practice

requirements and is easy-to-use, and can provide support for decision-making in promoting and introducing varieties. At the same time it provides information of maize variety and regional planting environmental characteristics.

Integrated seed companies and breeding enterprises can acquire the decision support information in promoting varieties, which can help their products be popularized to the appropriate region more accurately; seed retailers and agro-technical station can obtain the support information in stocking varieties, which can improve the pertinence and validity of their spread, leading to the increase of yield.

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A PDA-BASED FEEDING EXPERT SYSTEM FOR INDOOR INTENSIVE CULTURING OF SOUTHERN FLOUNDER IN CHINA

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Abstract: This paper presents a research to develop and evaluate a PDA-based feeding support system for Indoor Intensive Culturing. Based on analysis of the feed fed The impact of various factors, the establishment of a knowledge base and fed feed the database, building a model of aquaculture feed formulation and decision-making model fed feed, feed formula to achieve the design, the volume of feeding, feeding time, feeding the number of decision-making and the knowledge base management functions of the three modules, which not only increased the number of aquaculture farms of the digital management level and reduced the cost of human resources, also for intensive aquaculture feedstuff fed policy-making to provide a new means of achieving.

Key words: PDA; intensive aquaculture; feeding; decision support system

1. INTRODUCTION

In China, the southern flounder supports valuable commercial and recreational fisheries throughout the geographic range it inhabits, which also plays a very important role in the intensive fish culturing factories and generating farmers' income (Roach J., 1987; James W.J., 1985; Jones,D.,1989). However, the traditional feeding ways can't meet its nutrient needs, supply good and enough fish for the present market and get a

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satisfactory economic interest for the farmers (Latin R.X, 1987; Stone N.D., 1987; Thieme R.H. Vadim Bulitko., 1997, 1999).

The cost of feed is usually the greatest operating cost in aquaculture, and may account for 40% or more of total operating costs in the southern flounder culturing system (Timmons and Losordo, 1994; Kuo, 1994). It has been estimated that over 60% of the feed placed into an aqua cultural system ends up as particulates (Masser, 1992). How to feed right is very important.

Some methods were developed to detect left over feed in order to stop feeding. Shepherd and Bromage (1988) estimated food waste by suspending a sheet below the sea cage during the feeding period, retrieving it after feeding, and counting the left over feed pellets. Juell (1991) and Juell et al. (1993) used hydroacoustic sensors to detect food pellets at 2.5 m depth in sea cages for feeding control. Foster et al. (1995) used an underwater camera and image analysis tool to detect and count left over pellets. Similar system is now commercially available for sea cage applications, sensors used including Doppler pellet sensor, CAS pellet sensor and camera sensor (Akvasmart, Norway). Kevin and Royann (2003) used the accuracy of a new machine-vision system for the identification of a feed wastage event and the response times are reported. Without using a feedback mechanism, Fast et al. (1997) used demand feeders and an automated data acquisition system to assess fish feeding rhythms. Acoustic and photoelectric sensors to detect turbidity of the effluent are also commercially available. Ultrasonic telemetric system was also used for automatic positioning of individual salmon in a sea cage (Juell and Westerberg, 1993).

Based on their previous study, this paper reports a research effort in applying southern flounder feeding in intensive culturing farming factories. It's developed by Agricultural Information Technology Institute of China Agricultural University and is a major outcome of an 863 Project funded by the National High Science and Technology Development Plan of the Peoples' Republic of China.

2. USERS' NEED FOR THE FEEDING SUPPORT SYSTEM

China is a large country but most aquaculture sites for southern flounder are scattered in seaside areas. Although fish farming is growing rapidly in recent years, the general level of farmers' skills and knowledge in fish farming is evidently low. An experiment is operated to demonstrate the fish output comparison between before and after users using the feeding machine, it is described as follows (Table 1).

Table 1 output comparison between before and after users using the feeding machine

	Before	After
Output of Southern flounder(kg)	480~500	550
Amount of Feeding stuff(kg)	8500	3700
Expenditure for Feeding stuff	1870	1628

Obviously, since the users use the feeding machine, not only the output of southern flounder has been distinctly increased, but also the cost has been saved a lot. At the same time, it reduces the labor expenditure. From the increasing economic interest, farmers can easily accept the feeding support system.

As a result of the emerging need for experts' help in fish feeding techniques, a feeding support system is going to be developed to help fish farmers with solutions to the problems they meet in practice.

3. SYSTEM FRAME AND FUNCTIONS

Based on users' needs analysis, a feeding support system is going to be developed and integrated to related Fish Expert. This support system mainly is comprised of seven sections, including knowledge base, inference engine, knowledge base management system, knowledge acquisition, explanation facility, interface and internet. The relation among them is as follows in Figure1.

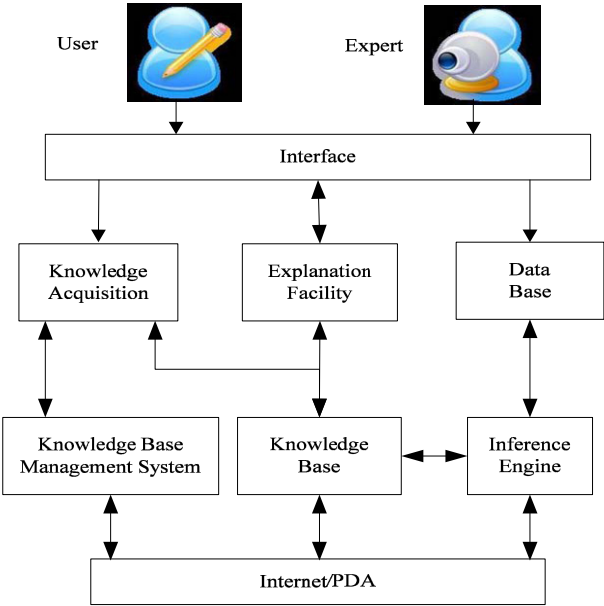


Figure 1. The structure of the feeding support system

4. SYSTEM COMPONENTS AND THE FEEDING PROCESS

In order to best meet the different needs of fish farmers, six feeding subsystems have been designed according to the different growing phases of southern flounder. They are a prophase fish fry feeding expert system, anaphase fish fry feeding expert system, post larval fish feeding expert system, juvenile fish feeding expert system; cultivate fish feeding expert system and adult fish feeding expert system.

4.1 Database structure and function modules

Six different subsystems are integrated in support system. It also contains a series of databases, which are needed for record-keeping and decision-making during the feeding process. For instance, typical databases include registration, user database, expert database, feedstuff database, fish database, etc. Every subsystem contains what kind of different function modules in the feeding expert system, which mainly have two modules: choosing feedstuff and feeding techniques. Choosing feed stuff needs to take four factors into consideration, which are respectively ingest habits, nutrients demand, feedstuff formula and make a feeding plan. The feeding techniques include domestication management, amount of bait, feeding methods, surplus feeding stuff.

4.2 Feeding process

For a particular fish species, assuming that it's in a growth phase, the total number of types of feed to be elected is m , the no. I feed is fixed as M_i , the Marxism and Minimum amount of the feed are respectively $m_i^{\max}$ and $m_i^{\min}$.

There are n kinds of necessary nutritions, among which the no j nutrition is recorded as N_j , the Marxism and Minimum amount of the nutrition are respectively recorded as $n_j^{\max}$ and $n_j^{\min}$, for each quantity unit of M_i , the percent of nutrition N_j is recorded as μ_{ij} , the price of feed M_i is recorded as c_i . The solution set of Formulation problem is in the form of a vector, according to the solution set, the daily feeding amount and the lowest cost of the feed can be easily got.

Suppose if the feed M_i 's daily supply is x_i , then the function can be described as follows:

$$Z = \min \sum_{i=1}^p c_i x_i$$

Restraint of feedstuff use:

$$\text{mimin} \leq x_i \leq \text{mimax}, i=1,2,\dots,u \quad (1)$$

Nutrient intake bound:

$$n_j^{\min} \leq \sum_{i=1}^p \mu_{ij} x_i \leq n_j^{\max}, j=1,2,\dots,v \quad (2)$$

Non-binding negative restraint for solution set:

$$x_i \geq 0, i=1,2,\dots,p \quad (3)$$

Using simplex method, the value of x_i can be easily got. So the quantity demanded of each feed is presented. Then the value of Z can be calculated out, which is the cost of formula in the condition of x_i .

Second, according to the value of Z and a which is the feeding coefficient that can be obtained from the database, the feeding quantity per time can be got through the calculation of the following function:

$N_1=a_1Z, N_2=a_2Z, \dots, N_q=a_qZ$ (N_q and a_q mean for no. q 's feeding quantity and feed coefficient).

5. SYSTEM IMPLEMENTATION

5.1 Platform Structure of System

The platform structure of PDA-based Feeding Expert System consists of knowledge engineer module, Serial conversion between the database module and expert system application module. Through knowledge engineers module, visualization of aquatic products to create a database of knowledge, rules and the yuan rules; then through the database of serial conversion component modules, will create a database simultaneously transformed into PDA; using the conversion of knowledge, according to the needs of users, the expert system application modules adopts a question-or-solving approach to decision-making experts, at last the conclusion can be obtained. The Platform Structure of System is shown in Figure 2.

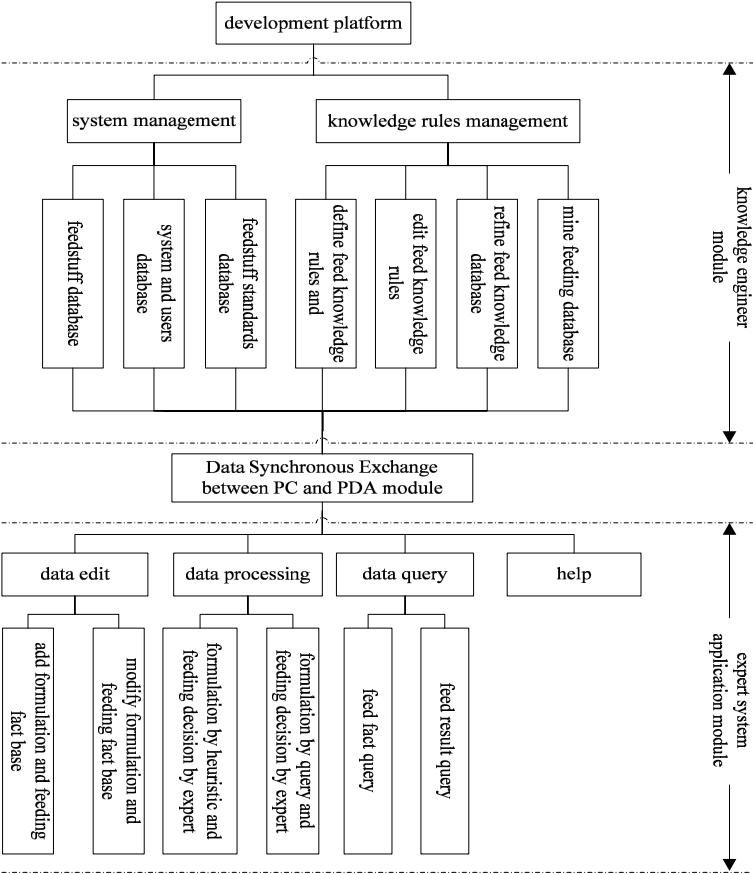


Figure 2. Platform Structure of System

5.2 Implementation

In Visual Studio 2005 environment, based on data management using C# and MsSQL Server 2005 CE, MsSQL Server 2005 for the desk PC database, a model of feeding formula, feeding model and user interface design were established; a PDA-based intensive aquaculture feed fed expert system was developed. The PDA is from Hewlett Packard (HP) company, the type is iPAQ 5965 with the system Windows Mobile 5.0 (version: 437809-012), processor SAMSUNG S3C2440 400Mhz. The feeding input interface and feeding expert system are shown in Figure3 and Figure4:



Fig 3. Input interface of system



Fig.4. Output interface of system

6. RESULTS AND DISCUSSION

This paper reports a research in developing and testing a feeding support system in aquaculture. The development process adopted a user-centered approach and users (fish farmers) were consulted regularly during each stage of development. As a result, the system components and its major functions are derived from users’ suggestions and needs. For example, the system was initially a feeding support system. Based on the need for real expert support, a feeding support system was developed and integrated into the expert system. Further improvement and testing are still being undertaken alongside the collection of more feedback from users.

Reduction of labor requirements represents an advantage of the system. It is expected that when personnel are more familiar with the system, the labor requirements may decrease further.

The research demonstrates the possibility and potential benefits of using the Internet to facilitate feeding support in aquaculture. As the performance of an expert system is limited by its knowledge, an ES is unlikely to perform as well as a real expert. It is hoped that the improvement and new development of networks and the rapidly decreased cost of IT equipment will eliminate the bottleneck in the future, thus the feeding support systems will be more practical and beneficial to end users.

7. CONCLUSIONS

The feeding support system presented provides a tool to enhance the management of southern flounder cultivation. When connected with monitoring systems currently available in the market the system shows potential to serve as a management system for intensive cultivation. Further improvement of the system will be possible by incorporating components such as controllers that could follow the potential fluctuations of the actual

requirements from the estimated ones and adapt the feeding tables accordingly.

The system has emerged as a result of the use of a PDA-based feeding expert system. It helps to overcome the limitations and enhance the functionality of traditional ESs. This research used this pilot system as a research vehicle to experiment in applying, and to evaluate the usability of the system with potential users. Feedback collected from the demonstration and evaluation of the system has provided valuable insights into the issues related to the development and implementation of feeding support system in aquaculture in China.

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DEVELOPMENT OF MULTI OBJECTIVE PLAN USING FUZZY TECHNIQUE FOR OPTIMAL CROPPING PATTERN IN COMMAND AREA OF AUNDHA MINOR IRRIGATION PROJECT OF MAHARASHTRA STATE (INDIA)

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Abstract: In order to consider the importance of efficient and judicious use of available resources, a case study was undertaken to allocate the land under selected crops in command area of Aundha Minor irrigation project, of Maharashtra State, India so as to maximize the net benefit and production. A linear programming allocation model was formulated by considering the four objectives viz. (i) the maximization of net benefit, (ii) the maximization of total production, (iii) the maximization and minimization of labour employment and (iv) the minimization of investment subject to the constraints dealing with the crops, soil, land, individual crop area, food and nutrient requirement, fertilizer and labour availability, irrigation water release policy, area restriction on individual crops were considered. Irrigation efficiencies of 50, 60 and 70 % were considered, while fertilizer availability was considered at 1.5, 2.0 and 2.5 times of present level along with unlimited availability. Single objective allocation model was developed by using Gam 205 package. Single objective alternate plan was worked out with the constraints of 1.5 times the present fertilizer availability and 60 % irrigation efficiency. The programme was verified by using Lindo package. Multi-objective allocation model was worked out using fuzzy technique to obtain a compromise alternate plan. As a whole compromised solution obtained under multi-objectives plan using fuzzy technique equally helps both the farming community and nation as a whole. In fact, the single objective net benefit optimization gave a benefit to the tune of Rs. 9665 ha-1 y-1, whereas the compromise solution by fuzzy technique gave better return to the tune of Rs. 10278 ha-1 y-1 as against existing benefit of Rs. 4310 ha-1 y-1. Farmers are advised to advocate the

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optimal cropping pattern obtained by multi-objective allocation model for better return.

Keywords: linear programming, irrigation efficiencies, fuzzy technique, optimization

1. INTRODUCTION

India has made considerable progress as far as irrigation potential created is concerned. The irrigation potential has increased from 22.5 million hectares in 1951 to 92 million hectares in 1996 against an ultimate potential of 113 million hectares. Out of this irrigation potential, the contribution of minor irrigation project alone constitutes about 38.6 million hectares. The number of minor irrigation projects is increasing. These projects mainly utilize surface water and each consists of small reservoir with a canal system for distribution of water. Unlike command area planning of major irrigation projects, no proper importance has been given to these tank irrigation projects for effective utilization of the resources. Thus, there is a need to develop an approach for efficient water management practices in tank irrigation projects.

In view of the massive investment in minor irrigation scheme, it is necessary that the scarce and expensive water resources be utilized judiciously to achieve higher economic efficiency. Therefore, effective and efficient utilization of existing tanks is necessary and the only way perhaps to achieve this is to adopt an integrated water management planning.

Integrated water management planning is a very complex phenomenon, which involves consideration of large number of possible alternate plans (Bhole, 1992). Integrated water management planning aims at increasing net benefit to the farmers with efficient crop production from available water resources, considering constraints of soil, crop management, farmer's limitation and socio-economic conditions. To handle complex water resources system of command area planning along with reservoir scheduling, the conjunctive use of linear programming (LP) and fuzzy technique is an appropriate approach to get a realistic solution. Considering the above factors, an attempt was made to undertake a systematic study of Wagarwadi catchment at Aundha minor irrigation, tank located in the Aundha Taluka of district Hingoli in the state of Maharashtra, India with the specific objectives of optional allocation of command area under different crops by Linear Programming and Fuzzy Technique and to work out the economics of alternate plans to compare them with the existing situations.

Determination of cropping pattern for command area of minor irrigation project finds an important place in crop planning for obtaining maximum net

benefit. It involves selecting a group of crops, which can be grown on an area out of number of feasible crop combinations. Crop selection is influenced by factors viz. water requirements, net returns, climatic conditions availability of resources, social needs, technological innovations and agronomic practices. In crop planning, efforts are made to project an optimal cropping pattern satisfying the objective for obtaining better returns. Optimal cropping pattern makes the best use of land and water resources.

2. MATERIALS AND METHODS

The Aundha minor irrigation project is located in Aundha Taluka of Hingoli District of Maharashtra State of India. It is constructed in an existing nala, which is originating from Dargegaon village and flows through the eastern side of Aundha Taluka and finally joins Purna river, which is a tributary of Godavari river. It is located at the intersection of 77° 2' E longitude and 19° 32' N latitude in Hingoli district, Maharashtra, India. The watershed area of the Project is 1190 ha. This has been taken as an average type of watershed for runoff calculation. The project envisages the construction of an earthen dam 400 m long and 15.5 m high to impound about 190 ha-m volume of water. The command area is spreaded over four villages namely Aundha, Wagarwadi, Kondsai and Asola. The gross command area of the project is 398.00 ha. Out of which 397.5 ha is cultivated command area.

Mathematical programme was formulated for Aundha minor irrigation project command area, considering various constraints like available land, crop affinity, fertilizer and water availability etc. Single and multiple objective mathematical programming models have been developed to find the best-allocation of resources to (i) various crops suitable for the agro-climatic conditions of the area (ii) animal husbandry and (iii) fodder, Cultivation. The models with single objective like minimization of net benefit to the farmers or minimization of investments have been developed to explore the impact of relaxing the various constraints. Single objective plans viz. maximization of net benefit, maximization of production, minimization of investment, maximization and minimization of labour were considered using the combination of different levels of fertilizer and irrigation efficiencies. Also multi-objective allocation model was worked using fuzzy techniques to obtain a compromise alternate plan (Paudyal and Dasgupta, 1990; Sahoo, 1990; Sinha et al., 1989; Tanka and Asai, 1984; Varshney, 1987). The multiple objective model developed serves two important purposes. Firstly, it gives a more realistic formulation and

secondly, a more acceptable solution to the problems as it can incorporate the conflicting objectives of a development-planning problem.

The fertilizer dosages recommended for different crops were taken as per the requirement. The fertilizer availability in command area headquarter was estimated by conducting survey in the area. The present fertilizer availability was found to be 330, 200 and 130 quintals of nitrogen, phosphorous and potash, respectively. In order to establish the optimal irrigation efficiency under given conditions, alternative plans have been introduced considering overall irrigation efficiencies of 50 per cent, 60 per cent and 70 per cent. The optimal irrigation efficiency will be utilized while working out other alternative plans.

3. RESULTS AND DISCUSSION

Detailed area utilization under kharif, rabi and summer with crop intensity and benefit for each of the 15 plans is presented in Table 1. The constraints of the cropping intensity (175 percent) forced all the plans to have the total area to be cultivated under kharif, rabi and summer to be 695.8 ha. However, the crop allocation influenced the fertilizer and irrigation efficiency to a certain extent. From the net benefit (Table 1), it is seen that there is need to go for 60 per cent irrigation efficiency and 1.5 times present level of fertilizer availability. The policy will enhance net benefit by more than 8 per cent compared to that of existing available fertilizer uses, while higher level of fertilizer availability can be best increase net benefit by 0.12 per cent only. An improved irrigation efficiency (70 percent) can also increase the net benefit by 0.3 per cent. Thus, It was finally decided to work out single objective alternative plans with the constraint of 1.5 times the present fertilizer availability (i.e. 495, 300 and 195 quintals of N, P, K, respectively) and 60 percent irrigation efficiency.

3.1 Single objective planning

These results were obtained considering 60 per cent irrigation efficiency and 1.5 times of the existing fertilizer utilization (Table 2). The details of the area allocation under rainfed, critical and fully irrigated conditions for kharif, rabi and summer season for each of the plans are explained. Table 2. also presents the allocation of cows, buffaloes and poultry birds. It is clear that the cropping intensity of 1.75 became a limiting factor in case of benefit maximization, investment minimization and for both labour maximization and minimization. Plans gave the crop intensity of 200 per cent critical irrigation appears to be useful for kharif and rabi crops to the tune of 262.45

ha and 176.18 ha, respectively for benefit maximization without considering the poultry industry. On the other hand, considerable area has been allocated under rainfed condition for both kharif and rabi seasons. In case of all other plans maximum irrigated area is allocated under production maximization. Interestingly, poultry industry is encouraged under benefit maximization and labour maximization plans.

The profit, production, investment and labour utilization under each of the single objective alternate plans are presented in Table 3. Both the benefit and labour maximization gave a net profit of about Rs. 31 million while all other plans provided less than half the amount. Production maximization provided a maximum production of around 22.43 thousand quintals. All other plans gave even less than half the production as compared to the production under production maximization. Investment minimization required Rs. 11.3 million to be invested while benefit and labour maximization require more than 2 times that amount. It is interesting to note that the benefit to cost ratio worked out between 1.1 and 1.2 for all the plans. Labour minimization used just half the labour needed under labour maximization plan. Infact the labour and benefit maximization require more or less the same number of labours. Incorporation of poultry drastically reduces the crop production from a possible maximum of 22.43 to a minimum of 12.40 thousand quintals (Production maximization). In other words, the nation is deprived of food, which is the primary concern of the state. The results drive to the need of a compromised solution, where the interest of both the farmers and the nation are equally taken care of. That is possible only by adopting the multi-objective planning.

3.2 Multi objective planning - optimization techniques

Fuzzy technique was chosen to find the compromise solution. Considering each of the single objective plans viz., benefit production, labour maximization and minimization of investment and labour. The pay off values is presented in Table 4. From the table the difference between the highest value (U_k) and lowest (L_k) were obtained and are presented in the same table utilizing this information all the single objective function were converted as constraints given below.

The new objective function for fuzzy optimization model will be to minimize F subject to all the constraints plus the above five constraints. The programme was run using again Gams package to obtain area allocation under different crops.

The net benefit, production, investment and labour under multi-objective, multi-objective planning for each of the crop allocation is presented in Table 5.

It is clear from the table that there was a decrease in the net benefit by 28 per cent, production by 34 per cent and labour by 24 per cent while investment increased by 60 per cent from respective optimal values. However, the cropping intensity of the compromised solution is 199 per cent which is much higher than the cropping intensities obtainable from net benefit maximization, investment minimization, labour maximization and minimization and is roughly equal to the one provided by the production maximization. Hence multi-objective allocation model has been used to find out the optimal cropping pattern. In case of optimal cropping pattern all the available resources are utilized very effectively.

In fact the single objective net benefit optimization gives a benefit to the tune of Rs. 8386 ha⁻¹ y⁻¹ considering only crop husbandry, while compromise solution by Fuzzy technique indeed helps better returns to the tune of Rs. 10278 ha⁻¹ y⁻¹.

4. CONCLUSION

The compromised solution obtained under multi-objective plan using Fuzzy technique has been found as promising procedure for achieving an optimal cropping pattern in the study area. This procedure can very well be adopted in other locations and immense benefits can be obtained for the farming community.

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RESEARCH ON THE CONTROL OF REACTIVE POWER COMPENSATION BASED ON FUZZY REASONING

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Abstract: With the development of the rural power grids increasing gradually, there are higher requirements needed for its operation in reliability and economy. Reactive compensation using shunt capacitor at both ends of the load, reducing current of lines, and improves the power factor of system. The objective is to reduce losses of line, and improves the quality of voltage and the utilization of electrical equipments. In the switching control of compensation device, using voltage and reactive power these two factors to control, this is the fuzzy control. The range of voltage and reactive power are divided into several regions to determine the membership of each region. Using MATLAB simulation achieves a design method of fuzzy reasoning logic control, and gets an ideal control results.

Keywords: fuzzy reasoning, reactive power compensation, method of control, MATLAB simulation

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1. INTRODUCTION

With the growing scale grid, its economy and reliability requirements are also getting higher and higher. Improving the power grid operation quality and power factor grid and reducing network loss are a very important work (Wang Chun et al., 2008). In fact, the existence of a large number emotional load, reduces the power factor greatly, increases loss of active lines in result, lowers users voltage, makes the power equipment not fully applied and undermines the stability of the power system, and other adverse conditions (Wu Gongwen et al., 2008; Yu Haisheng et al., 2000). When a serious lack of reactive power collapses the entire system, a rational approach is reactive power compensation device installed where necessary reactive power consumption needed (E Zhijun et al., 2008; Liu Liming et al., 2002).

2. THE PRINCIPLE AND PURPOSE OF REACTIVE COMPENSATION

Reactive power compensation is the substance of the circuit to reduce the inductive reactive power, commonly used method is the inductive load paralleled with an appropriate capacitor, as shown in Fig. 1 (Gao Bo et al., 2003).

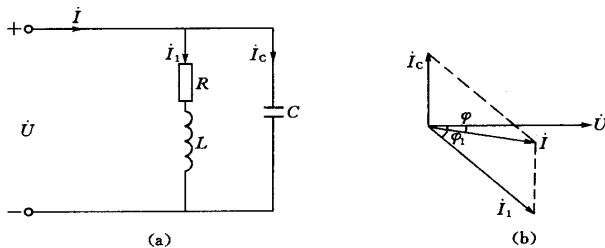


Fig.1: The principle of reactive power compensation

(a) Equivalent circuit of reactive power compensation (b) Reactive compensation vectors

Shunt capacitor C , circuit current $i = i_1$, angle φ_1 lagging behind voltage.

Shunt capacitor C , circuit current $i = i_1 + i_c$, φ decreased, but the power factor $\cos \varphi$ will be changed bigger, thereby, the entire circuit of the power factor will be improved too (Liu Shumin et al., 2002).

Reactive power compensation or improving power factor in network has a very important practical significance and economic benefits in reducing line losses, improving the voltage quality, and increasing efficiency in the use of electrical equipment (E. M. John, 2002; Xiong Hugang et al., 2008).

(1) Reducing power losses in power grids and power loss

When the active power P fixed in value, and $\cos \varphi$ inversely proportional to load current I , and reactive power compensation equipment installed by the formula $I = P / (U \cdot \cos \varphi)$, power factor $\cos \varphi$ will be improved to decreases the current line, so that line loss ΔP will be lower:

$\Delta P = I^2 R$. Therefore, the main purpose of installing reactive compensation equipment is to reduce line losses in the power system (Mao Meijun, 2007).

(2) Improving the voltage quality

Calculation formula for the line voltage loss ΔU :

$$\Delta U = \frac{PR + QX}{U_e}$$

ΔU ——line voltage loss kV

P ——active power MW

Q ——reactive power MVar

U_e ——rated voltage kV

R ——lines of resistance Ω

X ——line inductive reactance Ω

From that, when the line of reactive power Q reduced the voltage loss ΔU also has been reduced (Cai Zhongqin et al., 1998).

(3) Increasing the power supply capacity equipment

From the $P = S \cdot \cos \varphi$, when the apparent power equipment S certain, power factor $\cos \varphi$ improved, P in last formula will also be increased, electrical equipment meritorious effort will also be increased too (Tang Yong et al., 1995).

(4) Reducing Users electricity costs, lowering production costs, and avoiding the low power factor off the electricity sector fine (P. Douglas et al., 1999).

3. THE METHOD AND REALIZATION OF FUZZY CONTROL

Generally, reactive compensation of electrical net adopts automatic switching device, they are deserved to in-depth study, how to control to-and-fro switching problem of compensation device, which is the best control method (Xu Yonghai et al., 2006). Fuzzy mathematics is a subject which researches and disposes fuzzy phenomenon (Liu Xiaochuan et al., 2000). It can't use classical mathematics to generally estimate and control electrical net's state which is a fuzzy concept.

It is a best method to carry through general fuzzy estimate with applying fuzzy discursion in control capacitor's switching device.

According to simulation of MATLAB and the control rules of voltage, five fuzzy subsets reflect deviation with voltage deviation as input variable, that is, NO(Normal), LO(Low), MI(Minimum), HI(high), MA(Maximum), fuzzy domain is $[-2, 2]$; With reactive power deviation Δc as input, nine fuzzy subsets reflect deviation, that is, NH(negative high), NS(negative small), NM(negative mediate), NB(negative big), NO(zero), PS(positive small), PM(positive mediate), PB(positive big), PH(positive high), fuzzy domain is $[-4, 4]$.

Fig.2 and Fig.3 respectively descript membership function of voltage deviation and reactive power deviation with simulation of MATLAB.

Membership function converses the actual variable to linguistic variables, and determines membership of discrete fuzzy sets in linguistic value.

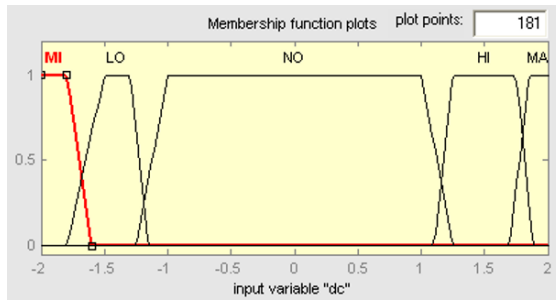


Fig.2: The membership function of Δu

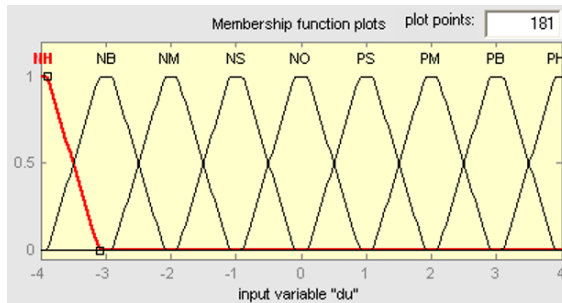


Fig.3: The membership function of Δc

Fuzzy ruling is described by nine fuzzy subsets, that is, NS(negative small), NM(negative mediate), NB(negative big), NA(negative all), ST(stable), PS((positive small), PM((positive mediate), PB(positive big), PA(positive all), fuzzy domain is $[-7, 7]$. Membership function is described by Fig.4.

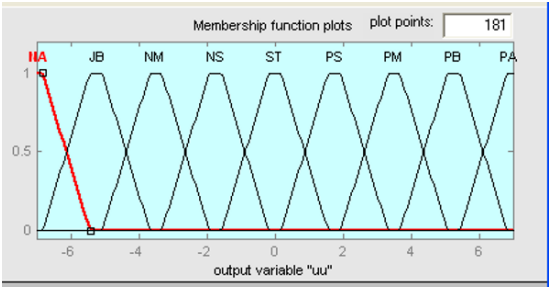


Fig.4: The membership function of U

Inference rules following the below are obtained by the debugging in scene and experience reactive power compensation.

- If Δu is NO and Δc is NS , Control Variable U is PS;
- If Δu is NO and Δc is NM , Control Variable U is PM;
- If Δu is NO and Δc is NB , Control Variable U is PB;

.....
Fuzzy state control table is described by table, according to 35 fuzzy reasoning language rules, as the following table:

Table 1. The general table of Fuzzy control rule

$\frac{\Delta C}{\Delta U}$	NH	NB	NM	NS	ZE	PS	PM	PB	PH
MI	NA	NA	NA	NA	NA	NA	NA	NA	NA
LO	ST	ST	ST	ST	-	-	-	-	-
NO	PA	PB	PM	PS	ST	NS	NM	NB	NA
HI	-	-	-	-	-	ST	ST	ST	ST
MA	NA	NB	NM	NS	NS	NS	NS	NS	NS

Each control rules can be obtained corresponding fuzzy relations , as $\tilde{R}_1, \tilde{R}_2, \dots, \tilde{R}_{35}$. So the corresponding fuzzy relationship of the entire system control rules is

$$\tilde{R} = \tilde{R}_1 \vee \tilde{R}_2 \vee \dots \vee \tilde{R}_{35} = \bigvee_{i=1}^{35} \tilde{R}_i \tag{1}$$

The fuzzy sets of corresponding control $\tilde{U}$ as follows can be obtained by membership function of Δu and Δc after getting overall fuzzy relationship ,not from the principle of the nearest whole of integer Δc and Δu .

$$\tilde{U} = (\Delta \tilde{u} \times \Delta \tilde{c}) \circ \tilde{R} \tag{2}$$

$$\mu_{\tilde{U}}(z) = \vee \mu_{\tilde{R}}(x, y, z) \wedge [\mu_{\Delta \tilde{u}}(x) \wedge \mu_{\Delta \tilde{c}}(y)] \tag{3}$$

The only obtained fuzzy vector above reflects a situation of the different fuzzy subset of Δc , Δu .Fuzzy issues should be considered because actually the charged object can only accept the control of a specific one.

There are many ways in the current ambiguity, such as the law of focus area, membership of the largest, and the weighted average method and so on.

The weighted average method is applied here, and precise control variables obtained, the following formula

$$U^* = \frac{\sum \mu_{\tilde{U}}(z_i) \times z_i}{\sum \mu_{\tilde{U}}(z_i)} \tag{4}$$

The control of variable U^* , which is obtained by the control table established on SCM and formatted with fuzzy and group switching capacitor guarantee load reactive power at the best value in the scope.

Fig. 5 is the Control variable value of Δc and Δu in (1, 4) .

Their surface map is described by Fig. 6.

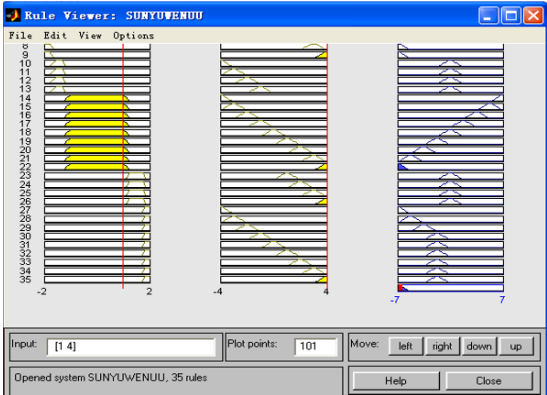


Fig.5: Input/output variable getting value table

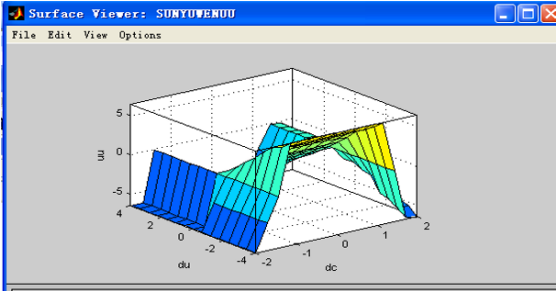


Fig.6: Input/output relation cambered face

4. CONCLUSION

Reactive compensation has a very important practical significance and economic benefits. Grid voltage level is determined by the system-wide balance of reactive power, usually voltage and reactive power compensation is not a function of the relationship between the curve, and family of curves. The important feature of fuzzy logic control is simple, only a two-dimensional logic form, that is the simulated experts operation (Guo Zongren et al., 2002).

Fuzzy reasoning simulation using MATLAB, with a voltage deviation Δu and reactive power deviation Δc as input, commonly controls switching capacitors, compensates for the inaccuracy the of the previous single factor control ,eliminates the unnecessary reciprocating switching, and improves the control strategy, and achieves the control of reactive power compensation based on fuzzy reasoning.

Obtaining the membership function of the voltage deviation and the reactive power deviation, the control of variable U^* , which is obtained by the control table established on SCM and formatted with fuzzy, and group switching capacitor guarantee load reactive power at the best value in the scope.

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RESEARCH ON IMAGE-BASED FUZZY VISUAL SERVO FOR PICKING ROBOT

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Abstract: An open eggplant picking robot experiment system is developed successfully which includes a arthral manipulator with 4 DOF, a motion controller, a color image processing card, a camera and a PC. The fixed bilateral threshold based histogram is adopted to segment the G-B gray images of eggplant in the growth environment.. To meet the vision requirement of the eggplant picking robot, the object's characters, such as outline, area, center of gravity, enclosing rectangle and the point to cut off, are extracted. We applied fuzzy control to the visual servo of picking robot and selected the fruit image's centre of gravity coordinate as variable for the fuzzy control system to create a fuzzy controller. The output control was modified by the self-adjustment factor and thus a fuzzy control diagram for the precise output control was obtained. The results show that the image-based picking robot fuzzy visual servo control overcomes time variation, nonlinearity and strong coupling of the robot visual servo control and has high response speed and good robustness.

Keywords: picking robot, image processing, visual servo, fuzzy control

1. INTRODUCTION

Harvest and picking takes much time and effort in the course of fruit and vegetable cultivation. Statistics shows that harvest and picking accounts for 50 to 70 percent of the total workload (Liang, 2005; Song, 2006). From the

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1980s, the Western developed countries such as Japan have been working at the picking robot and have developed artificial intelligence robot to pick vegetables and fruit (Kondo, 1996; Sario, 1993; Shigehiko, 2002). However, these vegetable and fruit picking robots can't adapt to the external environmental changes due to limited sensitivity, which affect their promotion (Hollington, 1999). With the development of computer vision, the visual servo system that combines robot control and robot vision provides conditions for improving robots' sensitivity and intelligence (Wang, 2005).

Since Hill and Park put forward the concept of visual servo in 1979 (Weiss, 1987), scholars at home and abroad have done numerous studies on robot visual servo and acquired some achievements in these years. But because of its complexities, there exist such difficulties as low speed in processing visual information and narrow appliance ranges. Visual servo control algorithm is still a challenge to be solved (Sun, 2006).

The present study is to develop a opening eggplant picking robot. The main objectives of the study go as follows:

- (1) To develop open picking robot experiment system based PC for eggplant.
- (2) To study the object's recognition and orientation in the growth environment.
- (3) To design the fuzzy controller of picking robot.

2. OPEN PICKING ROBOT EXPERIMENT SYSTEM FOR EGGPLANT

In order for vegetable and fruit picking robot to have favorable extensibility, commonality and flexibility, open architecture is used for the eggplant picking robot experiment system. The system is composed of a PC, a DMC2280 motion controller, Y-E DATA AC servomotor, DH-CG320 color image processing card, Panasonic WV-CP470 camera, a arthral manipulator with 4 degree of freedom, as shown in fig.1.

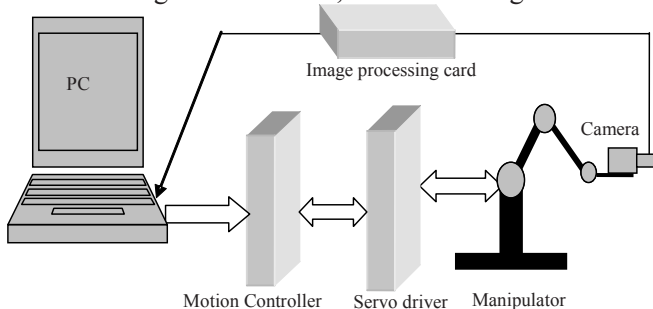


Fig.1: Schematic diagram of picking robot system

The picking robot control system is a master-slaved structure. The PC, as the master controller, runs the main robot control program, provides the user interface, and completes the Motion Planning. The DMC2280 motion controller, as the workshop controller, accomplishes the motion control for joint electric motor via the motor driving system.

3. IMAGE PROCESSING ALGORITHM

It is the task for machine vision system to distinguish the ripening fruits from the complex background based on the colors, sizes and shapes of the target fruits, and to extract their characteristics to determine their spatial location, in order to provide corresponding kinematical parameter for the robotic arm.

3.1 Image segmentation

Image segmentation in picking robot visual system is to extract and mark the eggplant fruits from the image, i.e., to segment the image into two parts: the eggplant fruits and the background. The fixed bilateral threshold based histogram is adopted to segment G-B gray image according to the analysis of the color characters of the eggplant fruits and surrounding.

In specific operation, as for input image pixels whose gray value is between 20 and 192, the corresponding output image pixels is given white (pixel value is 255), others black (pixel value is 0), as shown below:

$$g(x, y) = \begin{cases} 1 & f(x, y) < 20 \\ 0 & 20 \leq f(x, y) \leq 192 \\ 1 & f(x, y) \geq 192 \end{cases} \quad (1)$$

Where: $f(x, y)$ is the pixels gray values at (x, y) before being processed, $g(x, y)$ is the pixels gray values at (x, y) after being processed, and t is the threshold value. The result of image segmentation is shown in Fig.2.

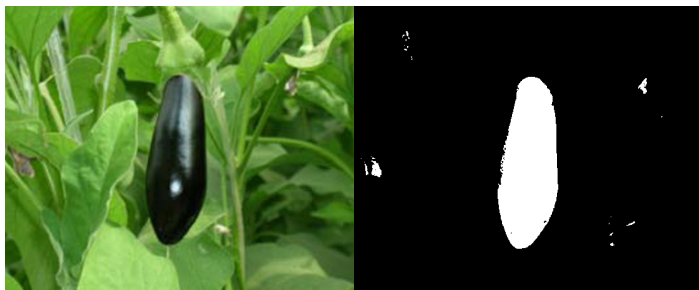


Fig.2: Result of image segmentation

3.2 Feature extraction of the target fruit

Picking robot needs machine vision system to provide characteristic parameters of the picking target, such as outline, area, center of gravity, enclosing rectangle and the point to cut off, etc. The contour has been labeled in two-dimensional array through edge extracting and contour tracing from binary image. In this way, it is convenient to extract the character desired for the target fruit. The result of feature extraction is shown in Fig.3.

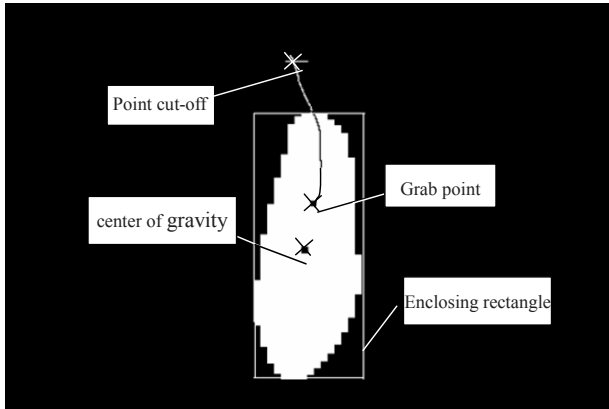


Fig.3: Result of feature extraction

4. IMAGE-BASED FUZZY VISUAL SERVO

4.1 Description of fuzzy visual servo control

The eye-in-hand configuration is applied to the visual servo system of picking robot. Target image information from the camera in the end effector of picking robot is used as input variable of the visual servo system. The fuzzy controller makes use of the input variable to determine the relative position between the end effector and the target and sends commands to complete the process of “perception- route choice -position adjustment-reaching target location”.

4.2 Design of fuzzy visual servo control

4.2.1 Selecting input variables for fuzzy control system

The image-based visual servo control needs to select proper image character to indicate the position relationship between the target and the robot because its task is to adjust the pose and position of the manipulator according to the picking robot job requirement. Thus the gravity center coordinates of the target fruit $G(\bar{x},\bar{y})$ is selected to reflect the relative posture between the target fruit and the manipulator. The difference value between the ideal value and current value acts as the input variable for the fuzzy controller. The wrist rotational motion $\bar{R}$ and vertical up-and-down motion $\bar{V}$ around the waist are selected as the output variable for the fuzzy controller. The block diagram of picking robot’s fuzzy controller is shown in Fig.4.

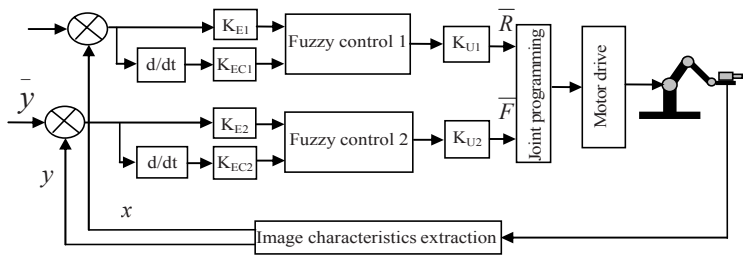


Fig.4: Block diagram of picking robot’s fuzzy controller

4.2.2 Fuzzification process of the fuzzy controller

The actual range of the input and output signals of the fuzzy controller is called the basic universe of the variable, which is the exact value. Before fuzzy reasoning, it needs to fuzzificate the exact value in the first place. The grades of the basic universe are to be classified because it needs to fuzzificate the exact value before fuzzy reasoning. There are certain requests for control precision and real-timing in accordance with the particular case of the vegetable and fruit picking robot. Therefore, the quantification grades for both the input variable and the output are classified as 12, namely:

$\{-6,-5,-4,-3,-2,-1,0,1,2,3,4,5,6\}$

The corresponding word set of fuzzy Language is chosen as:

$\{NB,NM,NS,O,PS,PM,PB\}$

Both the input variable and the output variable adopt Triangle-shape grade of membership function. The curve of membership function is shown in Fig.5.

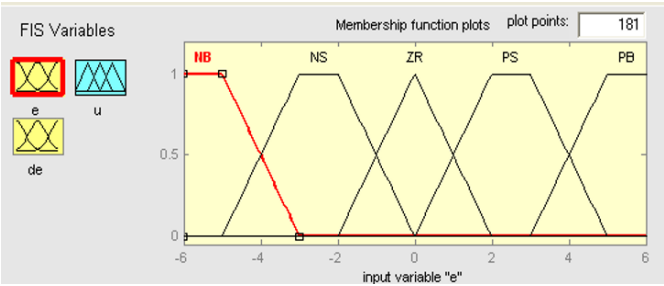


Fig.5: Curve of membership function

4.2.3 Fuzzy reasoning

It is through fuzzy reasoning rule to realize the mapping relationship between input fuzzy data and output fuzzy data. For the fuzzy controller in this research, the input is error E and error change rate Ec, and the output is U. There are the conditional statements of the fuzzy reasoning rules as shown by the following:

$$\text{if } E = E_i \text{ } Ec = Ec_j \text{ then } U = U_{ij} \tag{2}$$

Where: $i = 1, 2, \dots, 7$ $j = 1, 2, \dots, 7$

The membership function of the fuzzy relation can be expressed as:

$$\mu_R(x, y, z) = \bigvee_{i=1, j=1}^{i=7, j=7} [\mu_{Ei}(x) \wedge \mu_{Ecj}(y)] \wedge \mu_{Uij}(z) \tag{3}$$

Where: $\forall x \in E, \forall y \in Ec, \forall z \in U$

From the analysis of robot control, 49 reasoning rules can be established as shown in Table.1.

Table 1. Fuzzy control rule table

Ec	E						
	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PM	PM	PS	Z	Z
NM	PB	PB	PM	PM	PS	Z	Z
NS	PB	PB	PM	PS	Z	NM	NM
Z	PB	PB	PM	Z	NM	NB	NB
PS	PM	PM	Z	NS	NM	NB	NB
PM	Z	Z	NS	NM	NM	NB	NB
PB	Z	Z	NS	NM	NM	NB	NB

Therefore, the corresponding fuzzy relation for the main system control rule is:

$$R \bigcup_{i=1}^{49} R_i$$

(4)

The formula for seeking the control decision is $U = (E \times Ec)R$, namely:

$$\mu_U(z) = \bigvee_{x \in E, y \in Ec} \mu_R(x, y, z) \wedge [\mu_E(x) \wedge \mu_{Ec}(y)]$$

(5)

4.2.4 Defuzzication and the creation of fuzzy control table

The result from fuzzy reasoning is only a fuzzy quantity, which cannot be used directly for the controlled object. It needs to be converted in a precision quantity which can be run by an the executing agency through defuzzication process. The median method is selected to complete defuzzication process according to engineering application practice. The fuzzy control table corrected by the self-adjusting factors is set up, as is shown in Table 2.

Table2.Fuzzy control table

Ec	E												
	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
-6	6	6	6	5	4	4	4	4	3	1	0	0	0
-5	6	6	6	5	4	4	4	4	3	1	0	0	0
-4	6	6	6	5	4	4	4	4	3	1	0	0	0
-3	6	6	6	5	4	3	3	3	2	0	-3	-3	-4
-2	6	6	6	5	3	2	2	2	1	-2	-4	-4	-5
-1	6	6	6	5	3	1	1	1	0	-4	-5	-5	-6
0	6	6	6	5	2	0	0	0	-3	-5	-6	-6	-6
1	5	5	5	3	0	-1	-1	-1	-3	-5	-6	-6	-6
2	4	4	4	2	-1	-2	-2	-2	-3	-5	-6	-6	-6
3	3	3	3	0	-2	-3	-3	-3	-4	-5	-6	-6	-6
4	0	0	0	-1	-3	-4	-4	-4	-4	-5	-6	-6	-6
5	0	0	0	-1	-3	-4	-4	-4	-4	-5	-6	-6	-6
6	0	0	0	-1	-3	-4	-4	-4	-4	-5	-6	-6	-6

5. TEST RESULT AND ANALYSIS

Experiments have been carried out in the laboratory in order to verify the validity of image-based fuzzy visual servo control. The single background is set for the convenience of the test. During the test, a Panasonic WV-CP470 camera is installed on the fourth degree of freedom (the wrist) of the four-degree-of-freedom manipulator, whose resolution is set as 320×240, video speed is 10 frames/sec, and the sampling period is 100ms.

The objectives in the test are some eggplant fruits with a variety of shapes and sizes. The control task is to lay the center of gravity of the objective fruit in the center of the image plane. In the beginning, the eggplant fruit is lain in the filed of the camera vision, then the robot automatically adjusts its the position and pose until the objective image meet the requirements. Test curve of fuzzy control is shown in Fig.6.

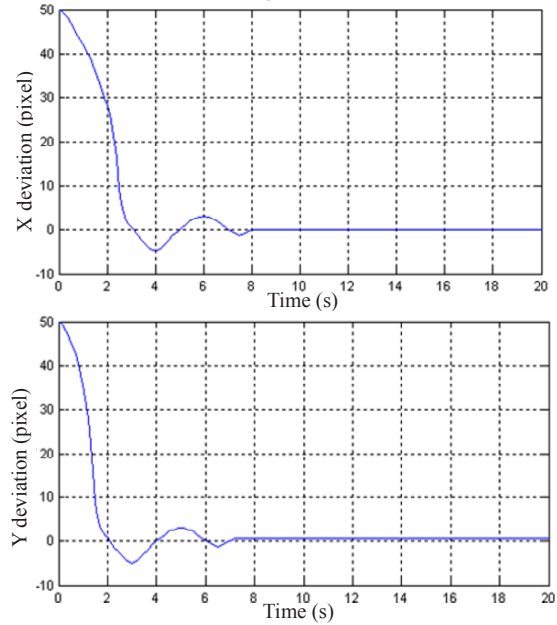


Fig.6 Test curve of fuzzy control

Step signals are inputted to 50 pixels for E_x and E_y respectively in the test. As can be seen from the figure, the control system responds fairly fast, and its steady state error is relatively small. Although there is certain steady state error, overshoot and oscillation, it can meet the demands of picking robot for the visual servo control.

6. CONCLUSION

1) The open f eggplant picking robot experiment system is established successfully which consists a arthral manipulator with 4 DOF, a motion controller, a color image grabbing card, a camera and a PC.

The application of fuzzy control to the visual servo control of the vegetable and fruit picking robot, not relying on precise objective models,

can overcome the influences of such factors as nonlinearity, close coupling and time-variation on the robot visual servo.

2) Histogram-based dual threshold method is adopted to segment G-B gray image and the contour has been labeled through edge extracting and contour tracing from binary image. This Image processing algorithm has some distinct characters, including simple and compact structure, high efficiency, and good real-time.

3) The coordinates of the center of gravity of the objective fruit is selected as the input variable for the fuzzy control system. The self-adjusting factors are used to revise output controlled quantity, thus creates the fuzzy control table for outputting precisely.

4) The application of fuzzy control to the visual servo control of the vegetable and fruit picking robot, not relying on precise objective models, can overcome the influences of such factors as nonlinearity, close coupling and time-variation. The test results show that image-based fuzzy visual servo control for the eggplant picking robot has fairly high response speed, good robustness

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DYNAMIC ALLIANCE OF AGRICULTURE PRODUCTS LOGISTICS BASED ON SWARM INTELLIGENCE

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Abstract: Along with the growing up of the Chinese generalized agriculture, the agriculture products logistics demands are increasing quickly in quality and quantity. Oppositely, the service of agriculture products logistics is slowly. It is very essential to study the logistics service mode suited to the tendency of the agriculture products logistics demand. The paper analyzes the common characteristic between the agriculture products logistics individual and the intelligence individual. Then, by the swarm intelligence, the dynamic alliance of agriculture products logistics is presented, the construction algorithm and the application method are given too. The paper provides a better operable development mode for the agriculture products logistics in China, which has directive meaning to improve the logistics efficiency for the socialistic new economy development and the New County Construction.

Keywords: agriculture products logistics, swarm Intelligence; dynamic alliance; multi individual

1. INTRODUCTION

Benefited from the Three Agricultural Policies and New Country Construction, Chinese generalized agriculture is growing up, agriculture and related industries are developing quickly. And the demand of agriculture

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products logistics is also increasing quickly in quality and quantity. Influenced by the thought 'emphasized production and despised circulation' in the traditional agriculture economy in China, agriculture products logistics in China started late and develops slowly, characterized by small-scale peasant economy; which limits the agriculture development and the production, circulation of the agriculture products. Thus, it is very essential to study the service mode of the logistics suited to the tendency to the agriculture products logistics demand.

Now, there are various problems in the agriculture products logistics in China, including low efficiency, poor quality, low informatization, few manpower etc.. For logistics individual, there are various modes, including the large enterprise; medium and small enterprise, self-employed individuals and farmers. Between these individuals, there are great difference in operation, management, specialty, lacking organization and platform. For the particularity of the agriculture products and its logistics, these are little logistics enterprise which can operate all kind agriculture products logistics. In fact, many logistics individual are competing repeatedly in low efficiency, low level market. The whole efficiency is very low. For instance, the proportion of the loss of vegetable product in logistics is about 5% in developed countries, 1-2% in America, but as high as 25-30% in China. That is, almost 80 millions tons vegetable is wasted every year (Zhao, 2005). If agricultural products logistics cost can be reduced, so is agricultural production expense, which leads to the increase of farmers' income.

For the rapid developing of the agriculture products logistics market and the problem of the logistics individual, it is essential to integrate the agriculture logistics service. The integrated object includes farmers, former material supplier, agriculture products collector, packing, transportation, warehousing, marketing, product planning, and information service (Meng, 2005). However, the integration on entity is very difficult, for a lot unfathomed problem in the operation management, benefit distribution etc.. And it is impossible to exist long-term stable organization for there is much difference between the individuals in the domain, manpower, ability and idea etc.. Then, the dynamic logistic organization has more advantage. At present, some research about logistics integration is mainly for industry logistics (Dai, 2004), little on agriculture products logistics.

The paper reveals that the agriculture products individual have the characteristic similar to the intelligence individual. By the swarm intelligence, the dynamic alliance of agriculture products logistics is presented, the construction algorithm for the alliance and the management of the alliance members are analyzed. Then, the creating, running, dissolving of the agriculture products logistics dynamic alliance is discussed.

2. SWARM INTELLIGENCE AND AGRICULTURE PRODUCTS LOGISTICS ALLIANCE

Agriculture products logistics individual, has a familiar cognition with itself, can make one or some logistics operation, which is looked as an individual with some level intelligence. By swarm intelligence, some agriculture products logistics may build up a dynamic alliance responding to the coming logistic job.

2.1 Intelligence individual and agriculture products logistics individual

The definition and explain of the intelligence individual have many edition. The intelligence mainly appears as some form as software or hardware of computer. Yet, they all have some commonness, such as, the highly adaptability and autonomy. Shoham (Shoham, 1993) regards that an entity is intelligence individual if its state includes the psychosis, such as knowledge, idea, promise and ability etc..

An individual which implements some operation of agriculture products logistics, as an independent entity which has knowledge, idea, ability and social duty, can be looked as intelligence individual. Then, the agriculture products logistics individual, as an intelligence individual, has the commonness: autonomy, social ability, flexibility, mobility, reaction, consciousness. This is the foundation for the making for the swarm intelligence alliance operation.

2.2 Multi individual swarm intelligence

In general, swarm intelligence is the characteristic which the entity without intelligence behaved intelligently. Swarm intelligence provides an approach to solve the distributed problem, but no need of centralized control and global model. By applying swarm intelligence, some algorithms have the characteristic of intelligence. By the interaction between the individual and environment, the algorithm has some self-organization function, robustly and visually. And, the theory of multi individual system is from distributed artificial intelligence, applied in many domains widely. Multi individual system mainly studies the corresponded intelligence action of the multi individual separated in logic or physics, and at last solves the problem.

Swarm intelligence based on multi individual, not only exerts the initiative, independence of the individual, but also makes the colony has the additional

function than the simple combined members have, presents more intelligence functions than normal intelligence individual.

2.3 Agriculture products logistics dynamic alliance

Under the well cooperation mechanism and fellowship, agriculture products logistics individuals connect and cooperate in related logistics work, then they can buildup logistics alliance (Bouckova, 2002). In fact, the logistics alliance is an integration platform based on information (Gunasekaran, 2004). Agriculture products logistics alliance includes the function like a real logistics enterprise; can implement the same operation, like warehousing, transportation, packing and etc..

In the environment of agriculture products logistics integration, the relation between the individuals is the cooperation fellowship based on credit, cooperation, and 'win-win'. Like the traditional integration mode, the fixed logistics alliance has many solidified default, e.g., the low adaptability for operation. Then the alliance needs to create and dissolve usually to adapt the logistics demand, which will waste more manpower, capital and resource, reduce the efficiency, and affect the fellowship between the individuals.

By the multi individual swarm intelligence, the paper abstracts the fellowship in the alliance construction, then buildup the agriculture logistics dynamic alliance adapted to the agriculture products logistics. Based on the dynamic alliance mechanism, every member understands the participant logistics operation deeply. Then, in cooperation, the members can implement the logistics work which can not by itself. The dynamic organization is more helpful to respond to the market rapidly, can exert more superiority and scale merit than the large enterprise.

3. THE MECHANISM OF THE AGRICULTURE PRODUCTS LOGISTICS DYNAMIC ALLIANCE

Agriculture products logistics dynamic alliance is timely and dynamic, creating for the logistics task and dissolving as the task end. The main idea of the formation algorithm of the dynamic alliance is as follows. At first, the system is droved by the coming logistics task; then the task is analyzed and decomposed. According to the sub task, the first generation combination of the logistics individual is generated randomly. Where, each sub task can include one or several logistics individuals. Then, each selected individual can select a group cooperation team with good fellowship. Repeating it, until the combination is stable, this is the last combination the task need.

3.1 Agriculture products logistics individuals database management

Based on the understanding about the agriculture products logistics, the agriculture products logistics individual member database is formed. The database keeps the information of the logistics members, including operation service domain, operation type, cooperator, enterprise scale, operation comprehensive assessment etc.. System formats the candidate logistics individual and adds it into the database. System can also maintain and make other operation to the member. Logistics individual member database and its management showed in Fig. 1.

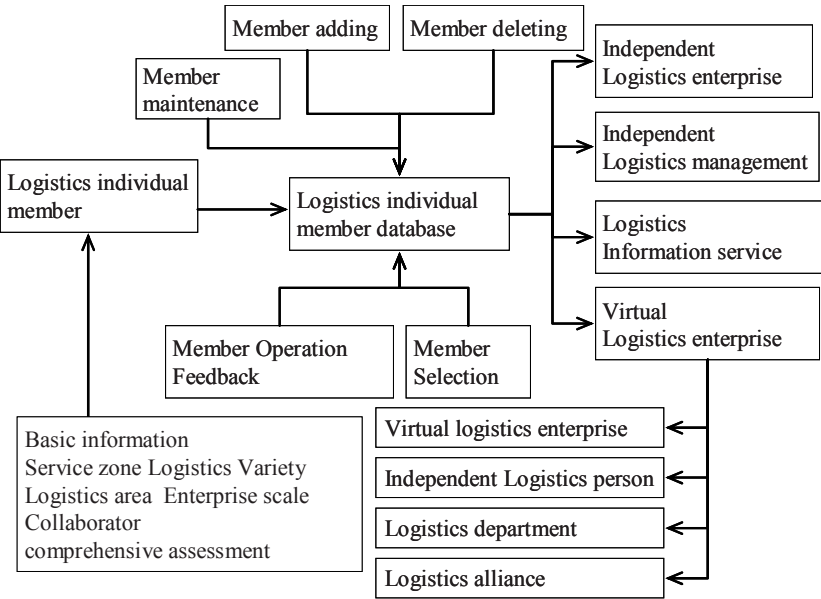


Fig.5. Agriculture products logistics individual member management in the dynamic alliance

There, the operation service range include: pre-logistics of agriculture products, primary gathering, primary processing, and warehousing, packing, transportation, distributing and information service. There includes two type basic individual, one is the entity logistics enterprise, which is the same as it in the real world; the other is virtual logistics enterprise, which maybe a department of a logistics enterprise, or a virtual enterprise combined in some approach. For some large agriculture products logistics enterprise, it can be added in the database as an independent enterprise, or can be decomposed as several virtual logistics operation and then added in database. Apparently, these virtual logistics enterprise decomposed by a large enterprise have more

near relationship, may select each other when cooperation. But in other environment, for efficiency and other reason, some integrated enterprise will select other fellow to complete a logistics work though it has sub enterprise about that work.

3.2 The algorithm of agriculture products logistics dynamic alliance

For a given logistics task, a multidimensional index space is formed, including the time, place, equipment, enterprise ability and service quality of the logistics task. The same number intelligence individuals are placed in the multidimensional space randomly, where each intelligence individual corresponding to a logistics sub task. The intelligence individuals are moving in the space and evaluated. At last, they are integrated by the multidimensional indexes.

Assume that the logistics member data set is $O = \{O_i = (o_{i1}, o_{i2}, \dots, o_{im}), i=1, 2, \dots, N\}$, is a set including N agricultural products logistics enterprise members. For one logistics intelligence individual O_i , $o_{i1}, o_{i2}, \dots, o_{im}$ are the performance index described before. Let

$$d_{ij} = \|P(O_i - O_j)\| = \sqrt{\sum_{k=1}^m w_k (o_{ik} - o_{jk})^2} \quad (1)$$

Where $d_{ij}(O_i, O_j)$ is the Euclidean distances between O_i and O_j ; expresses the cooperation willing between O_i and O_j in real world, P expresses the weighted integration, w_k is the weight, determined by the importance degree of the performance to a logistics task.

Before the selection of the individual cooperation, a candidate $area(O_i, d_r)$ are given, as the cooperation field of data object O_i , which expresses a group logistics individuals which cooperate nearly. d_r is the cooperation willing radius, expresses an integrated value of indexes.

When selection, O_i selects a cooperation group $A = \{A_i = (a_{i1}, a_{i2}, \dots, a_{ik}), a_{ik} \in O\}$ in $area(O_i, d_r)$, which satisfied the sub task. The selection basis of each a_{ik} is its d_{ij} is the least in $area(O_i, d_r)$.

$$d_{ij}(a_{ik}) \leq d_{ij}(a_{il}), a_{il} \in area(O_i, d_r) \quad (2)$$

Based on the group selection algorithm, the algorithm for the agriculture products logistics dynamic alliance is as follows.

(1) Task analysis and decomposing. The logistics task from the management system is analyzed and decomposed by the type described in Fig.1. The sub task type m and task require (sub task) $Q = \{q_1, q_2, \dots, q_m\}$ are generated. The object evaluated index $B = \{b_1, b_2, \dots, b_m\}$ are generated at the same time. Set the round number e .

(2) Alliance initialization. By the sub task Q, m intelligence individuals are generated from the database randomly, and the parameters (efficiency, domain, time and other) corresponding B are generated at the same time. This part makes randomly, or can be done by one task founder. These m intelligence individuals compose the first generation group.

(3) Generate the criterion for the intelligence individual to select cooperator. The first is the characteristic of the task (time domain, space domain, task composing, task volume, task precision, industry scope, etc.), then is cooperation relationship, business system etc.. Considering these factors synthetically, an intelligence individual corresponding to a sub logistics task, can select one or several cooperators. After a round selection for all intelligence individual in the last round group, a next generation group generates and replaces the old one. And select the new dr. This step mainly adopts the algorithm described before.

(4) For $i = 1, 2, \dots, n$, for each intelligence individual in the group, observe radius dr, search optimal cooperator group. In search, in the area(O_i , dr), by the need of the sub task, calculate the cooperator distance d_{ij} , if little than the individual in the candidate group, replaced the old one with it.

(5) After a round search, an alliance scheme generated. For the individuals in the alliance are from different selection of each individual in the last round, the individual in the alliance scheme may conflict each other, and then there need a filter. The criterion for filter is that in an alliance, there only keep the optimal individual group to complete the sub task. The filter algorithm can adopt many modes. The simple mode 1 is to limit the capability of each logistics sub work for the task. The simple mode 2 is to limit the individual counts in each round group.

(6) Judge if the algorithm should end. If end, goto step 7; or goto step 4 to start a new round to generate a new alliance scheme. The end condition can be the search times arrives the round number e. Or the condition is the object index arrive the precision. i.e., the algorithm has convergent.

(7) Assign the task to the real enterprise and implement it.

(8) After the task completes, by the performance of the member in this task, adjust the evaluation of the logistics individual member and give feedback to the database.

4. THE IMPLEMENT OF THE AGRICULTURE PRODUCTS LOGISTICS DYNAMIC ALLIANCE

Agriculture products logistics dynamic alliance, cored by the cooperation relation selection algorithm based on the multi individual swarm, droved by

logistics task, sustain by logistics individual database management system, implementing the integration of the agriculture products logistics. The main structure is shown in Fig. 2.

The operation of the agriculture products dynamic alliance includes the creating, running and dissolving. Each member implements one logistics operation, and with the cooperation the alliance completes the logistics task in the end.

In the course of implement, the management system and information platform provide the connection for the logistics individuals. There, each logistics individual member can accept order. Then, based on this algorithm, by the share information platform and the logistics individual database this individual can acquire the necessary information, select the cooperator and form the dynamic alliance, then to carry out the logistics job.

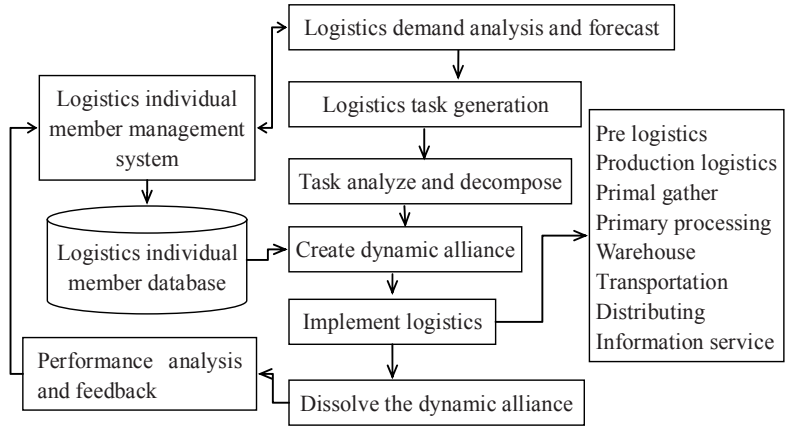


Fig. 6. The implement of the agriculture products logistics dynamic alliance

5. CONCLUSION

There exist serious dissymmetry between the quick increasing demand of agriculture products logistics and the slow service. Agriculture products logistics dynamic alliance provided a suitable mode for agriculture products logistics. The paper presents a member cooperation fellow selection algorithm based on multi individual swarm intelligence. Based on this algorithm, little and media logistics individual can organize together dynamically. One side, this method can exert the advantage and improve the efficiency of the member; the other, the service ability and quality can be improved. Based on the algorithm, the paper studies the creating, running, dissolving of the agriculture products logistics dynamic alliance, which theory is feasible. Because the application need great data, the algorithm just

has been emulating in lab. In emulation, among the given 30 logistics enterprises, a vegetable logistics dynamic alliance composed by 7 enterprises have generated, which performance excels than a actual selection by a group of experts. At last, in application, there are many problem need solve, including the alliance management, credit system, performance evaluation etc.. The depth on theory and width of application are the tendency of the following study.

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THE TEMPERATURE FUZZY CONTROL SYSTEM OF BARLEY MALT DRYING BASED ON MICROCONTROLLER

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Abstract: The control strategy of temperature and humidity in the beer barley malt drying chamber based on fuzzy logic control was implemented. Expounded in this paper was the selection of parameters for the structure of the regulatory device, as well as the essential design from control rules based on the existing experience. A temperature fuzzy controller was thus constructed using relevant fuzzy logic, and humidity control was achieved by relay, ensured the situation of the humidity to control the temperature. The temperature's fuzzy control and the humidity real-time control were all processed by single chip microcomputer with assembly program. The experimental results showed that the temperature control performance of this fuzzy regulatory system, especially in the ways of working stability and responding speed and so on, was better than normal used PID control. The cost of real-time system was in quite competitive position. It was demonstrated that the system have a promising prospect of extensive application.

Keywords: fuzzy control, single chip microcomputer, barley malt drying, temperature control system.

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1. INTRODUCTION

With the higher up of living standard of China, beer consumption is increasing greatly in recently ten years. Nowadays the main barley suppliers are European, North American, Australia. In the world, the total yield of barley was about 152.39 million tons in 2004 (Ju Fang, et al.2007), and planting areas were 61.6 million hm^2 in 1990s (Gu Zifen, el al. 2001). The Asian barley malt is about 21% of the global production, and the production of Northwestern areas is more than 1/3 of China (Gu Zifen, el al. 2001). Because of good irrigation farming condition and longer sunlight period, more and more farmers began to plant barley, the original materials of beer brewing, especially with the field planting plan changed for agricultural economic effects in Hexi Corridor of Gansu (Chen Bin. 2006). As the most population country of the world and half of barley import from aboard, therefore it is necessary for China's local barley malt enterprises to consider how to develop a kind of suitable high technology process in barley malt drying and also is urgent to control their product quality (Industry standard of P. R. of China-beer barley malt, 2003; Industry standard of P. R. of China-beer barley malt, 2003). At present most drying control measurement system used PID or relay circuits even few by hands, with the development of advanced control and microcomputer technology, several control systems were developed and got application in staple grain drying (Marchant J A. 1985; Courtois F., el al. 1995). This article will present the drying control experimental system based on fuzzy logical control strategy in the temperature and humidity control process of the columned barley malt drying chamber. It is beneficial for intelligentization and automatization of agricultural equipment.

2. MATERIALS AND METHODS

2.1 Devices of drying control system

Based on the further processing demand situation of Gansu agricultural products, and cooperated with Lanzhou Zhongchuan Barley Malt Corporation Limited, our research group selected the columned barley malt drying chamber as the temperature and humidity control implemental equipment of the national project of spark plan No.2006EA860002, supported by the Ministry of Science and Technology of the People's Republic of China. With the availability and reliability of the MCS-51 serial microcontroller and its abundant developmental compiler, the experimental

apparatus is constructed and shown in Fig. 1. It is composed of blower1, adjuster 2, speeder of VVVF, that is variable voltage and variable frequency inverter 3, electric motor 4, single chip microcontroller and its control circuits 5, temperature sensors 6, humidity transmitter 7, drying chamber 8, solid state relay 9, exhaust fan 10 (Liu Xueqiang, et al.2002) .

The figure 2 shows the all data acquisition and control system of drying experimental system. It is made up of AT89C51 microcontroller, temperature transmitters, humidity transmitters, amplifying and conditioning circuits, A/D converter, D/A converter, and power executive circuit.

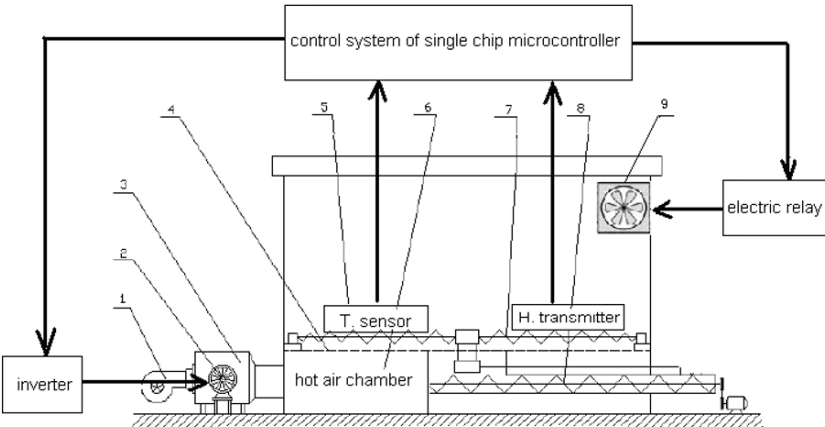


Figure 1. Schematic diagram of drying experimental apparatus

Where ADC0809 from National Instruments was selected as A/D converter, its function includes a 8 channels of analog input and 8 lines of digital output, and it is convenient to interface with microcontroller. You can program each channel with a different address control to maximize 8-bit analog-to-digit converter (ADC) resolution and measure the input signal. In this article, we selected the reference voltage to 5V, so the input range is from 0 to 5 voltage, and the measured precision is 19.53 mV. Channel 0~5 are configured to acquire the temperature and humidity and digital output is configured to interface with the microcontroller.

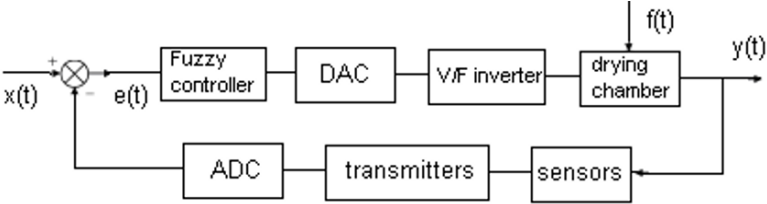


Figure 2. Flowchart of control system

AD590 two-terminal integrated circuit temperature transducers are used to measure heated medium, waste steam and surrounding, which produce an output current proportional to absolute temperature. For supply voltages between 4 V and 30 V the device acts as a high impedance, constant current regulator passing 1 $\mu\text{A/K}$. Laser trimming of the chip's thin-film resistors is used to calibrate the device to 298.2 μA output at 298.2K (25°C).

Chamber humidity is acquired by HS1101 relative humidity transmitters, its configuration features are suitable for linear voltage or frequency output circuitry separately, and measurement range is from 0 to 99%, while the typical frequency output is 7351-6033 Hz and voltage up to 3.55 V. V/F inverter is used for blower motor speeder controlling hot steam velocity of drying.

2.2 Drying control method and fuzzy controller design

During the drying experiment, we must keep the drying temperature invariably to meet the process demand of experiment (Liu Ying, et al., 2004). The precise model of nonlinear and time-varying control object is difficult to establish, so the fuzzy control algorithm is applied in this paper in order to implement the precise control goal (Li Guofang, et al., 2007; Li Changyou, Ban Hua.,2008). The controlled temperature fluctuation-residuum between initiation and measured value, residuum changing rate and output control parameter must be processed in fuzzy logical language, its discretized classifications of universe range are set in 13 quantization steps and fuzzy sets are 7. With the benefit of the MCS-51 serial microcontroller, the basic fuzzy system is constructed to realize the fuzzy logic control. The key points of fuzzy controller are how to decide the favorite input and output fuzzy membership functions. In this paper, with the consideration of the system stability, the continuous Gauss Function is selected for input membership function. Fuzzy logical consequence is deduced by Mamdani comprehensive implication rules. Weighted arithmetic mean method of fuzzy decision is used to get precise output control value (Li Shiyong., 1998).

So drying fuzzy logic control was applied to control the motor speed in this paper. The single-chip microcontroller calculates and sorts the output control value using fuzzy algorithm program according to the input signal values which are acquired by transducers and amplifying and conditioning circuits. The amplitude of inverter output can be controlled by the on-time digit-to-analog converter during controlling periods, which proportionally decides the output frequency of V/F inverter and the voltage supplied to motor.

2.3 Drying control system program

Assembly language is one of programming language that instruction of memory help symbol and operation data determines how to create application. In contrast to the advance programming languages, its storage spaces of responding machine codes are quite saving and its program execution is especial accurate (Zhang Yigang, el al.,1998) .

A barley malt drying experimental system based on assembly language was developed in this paper. Under the MCS-51 programming surrounding, the system control module and flowchart of drying experimental system is shown in figure 3. When the last step that is key process and parameter display is fulfilled, the program will return to the second step. In this way, a recycle testing and control program is realized and executed (Ding Yuanjie, el al., 2002).

The system is made up of system auto-diagnosis and initiation values given module, temperature and humidity A/D acquisition module, input signal data storage and processing module, keyboard process and temperature as well as humidity display module, fuzzy algorithm module, D/A output control module, error and annunciator module (He Limin, el al., 2007). Every module is programmed as a subprogram. Temperature and humidity A/D acquisition module acquires the experimental temperature and humidity through one of the analog input channels in ADC 0809 chip and

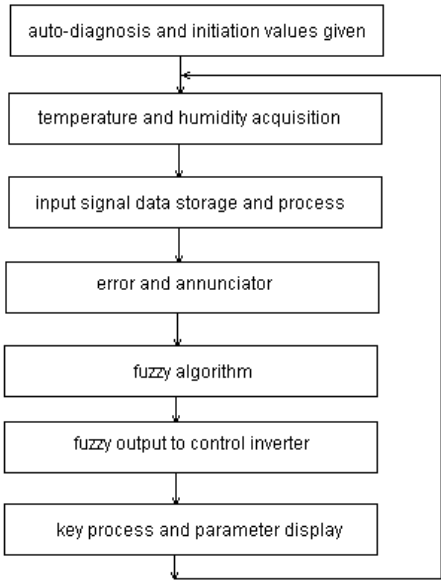


Figure 3. System control module and flowchart of drying experimental system

gives the measured results to other module for storage, diagnosis, control and display. Input signal data storage and processing module filters and stores data onto given register units of internal RAM of microcontroller for further fuzzy control and display. Keyboard process and temperature as well as humidity display module acquires key operation command or signal in interrupt way and displays surrounding sampled parameters according to the relation between the moisture and change of barley moisture removal rate. Figure 4 is the block diagram of this fuzzy algorithm module applies the fuzzy algorithm to deduce the output control value which is sorted by the table of control set strategy. D/A output control module outputs the analog voltage converted by ADC0832 to control the motor inverter to meet the need of the barley malt drying experiment. Error and annunciator module calculates the experimental measured error and gives an alarm if measured value surpasses the given temperature.

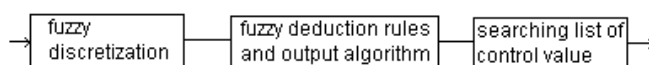


Figure 4. Block diagram of this fuzzy algorithm module

3. FUZZY CONTROL SYSTEM APPLICATION OF SIMULATION

This experimental system was configured and applied to make experimental study of barley malt drying process. The interval is 10 minutes for measuring mass change in the experiment. The simulation application shows that the operation of this experimental system is convenient and reduces the upper workload of drying measurement and shortens the period of drying process (Liu Jinkun., 2004). The procedure is comparatively precise and the precision of temperature control is $\pm 0.5^{\circ}\text{C}$ which meets the requirement of the barley malt drying process. During the experiment of the experimental process simulation, the control results meet the experimental drying process while the parameters of control are modified. This system is applied to the experimental drying process and acquires data in the study of the barley malt drying control system design, which will be used in the plant in the near future.

4. CONCLUSIONS

In this paper, using MCS-51 assembly language, fuzzy logical control algorithm and weighted arithmetic mean output control method, a unique experimental control system is developed for drying process and regulation studies. This fuzzy experimental system has been put into use and provides reliable and precise. The simulation results showed that the fuzzy control drying system has a better control precision of temperature and humidity and quick discriminating quality with powerful data processing and analyzing functions. The specific conclusions are as follows.

1. Under the general and flexible MCS-51 programming situation, fuzzy logical control and data acquisition software can be developed conveniently.

2. Using fuzzy logical control algorithm and weighted arithmetic mean output control method, this system is precise and reliable in automatic data acquisition and experimental processing control.

3. Compared with the traditional drying system, this fuzzy experimental drying system, which is a key unit of drying process, is simple in construction. The structure and functions can be expanded easily.

4. Automatic fuzzy control system will enhance the labor productivity, and its performance directly affects the product quality and benefits of the whole barley malt processing plant.

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A FUZZY CONTROL IRRIGATION SYSTEM FOR COTTON FIELD

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Abstract: A fuzzy control irrigation system for cotton field is presented in this paper. The system is composed of host computer, slave computer controller, communication module, soil water sensors, valve controllers, and system software. A fuzzy control model is constructed to control the irrigation time and irrigation quantity for cotton field. According to the water-required rules of different cotton growing periods, different irrigation strategies can be carried out automatically. This system had been used for precision irrigation of the cotton field in Langfang experimental farm of Soil and Fertilizer Institute, Chinese Academy of Agricultural Sciences in 2006. The results show that the fuzzy control irrigation system can improve cotton yield and save much water quantity than the irrigation system based on simple on-off control algorithm.

Keywords: fuzzy control, precision irrigation, sensor

1. INTRODUCTION

Soil water content collection is critical for precision irrigation (Zhao Yandong et al., 2002). Once the soil water contents are collected on real time, irrigation model can be developed combining with the plant water-required rules, and then correct strategy can be executed in time (Sun Li et al., 2005). In order to realize precision irrigation, computer control system should also

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be adopted besides computer measurement system (Xin Xiuli et al., 2005; Yang Qing et al., 2006; Sun Li et al., 2006). A fuzzy control irrigation system for cotton field is presented in this paper. Soil water sensors are used to collect soil water contents in different plots. According to the water-required rules of different cotton growing periods, the fuzzy control model is constructed to determine irrigation time and irrigation quantity automatically. The main functions of the system include real-time data collection, data processing, communication, and irrigation management. The results of experiments show that the fuzzy control irrigation system can improve production efficiency greatly.

2. COMPONENTS OF FUZZY CONTROL IRRIGATION SYSTEM

2.1 Hardware Components and Host Computer Software

Hardware components include host computer, slave computer controller, communication module, soil water sensors and electromagnetic valve controllers. The system structure is as Fig.1.

The main functions of host computer in the control center are to process data, realize the system control algorithm, manage the devices, and monitor the system operation. Cable communication transfer is not economic and convenient because of the long distance between the control center and the cotton field. Therefore SRWF-105 wireless communication module is used to realize the communication between host computer in the control center and slave computer controller in the field. SRWF-105 module provides two serial-communication interfaces, i.e. COM1 is UART interface of TTL voltage and COM2 is standard RS-485 interface. The module can realize remote communication within 2K meters.

The slave computer controller consists of MCU SPCE061A, extended memory, LCD display, keyboard, and RS-485 interface. The main functions of slave computer controllers are to collect soil water data, transmit data, display data, and control the behavior of electromagnetic valves. Soil water sensors and electromagnetic valve controllers are linked to slave computer controllers by RS-485 interfaces. The system controls the turning on/off of electromagnetic valves according to fuzzy control algorithm to realize precision irrigation automatically.

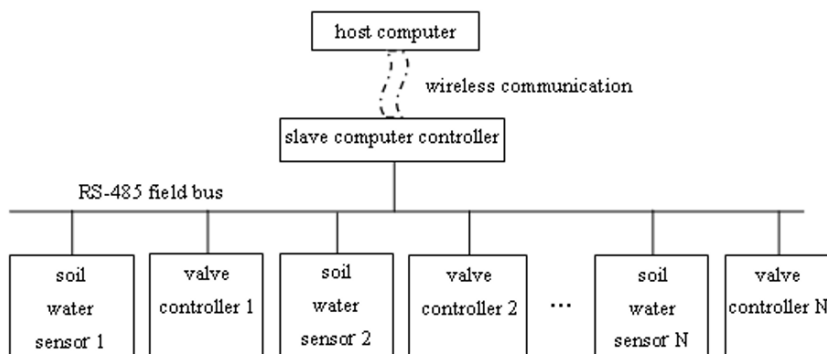


Fig.1. Fuzzy control irrigation system structure

Host computer monitor software is programmed by Visual Basic language. Slave computer control software is developed by C language and Assembly language. The system can operate under host computer monitoring or under only slave computer control without host computer monitoring. Host computer monitor software consists of data collection module, data processing module, communication module, and management module.

2.2 Fuzzy Control Model

Irrigation control has many characteristics, for instance, slow change and large delay, so that it's hard to construct an accurate mathematic model for it. On-off control algorithm is one of the simplest methods to control irrigation. The maximum and minimum thresholds of soil water contents are preset. When soil water content is detected to be lower than the minimum value or be higher than the maximum value, electromagnetic valve is turned on/off automatically to start/stop irrigation. Because the change of soil water content has large delay, this control algorithm is not very accurate, especially when soil water content is near the control threshold (Kuang Qiuming et al., 2007).

In order to improve control accuracy, two-input and one-output fuzzy control model is constructed in this paper. If the measured soil water content is y , the presetting soil water content is r , then the two inputs are the error e ($e=r-y$) and the error change rate ec ($ec=y(n)-y(n-1)$). The sampling period of the system is 5 minutes. The output u of the model is the valve turning on time. Single point fuzzy method and central average value inverse-fuzzy-method are adopted in the fuzzy controller (Zhang Weiguo et al., 1999).

The structure of the fuzzy controller is as Fig. 2.

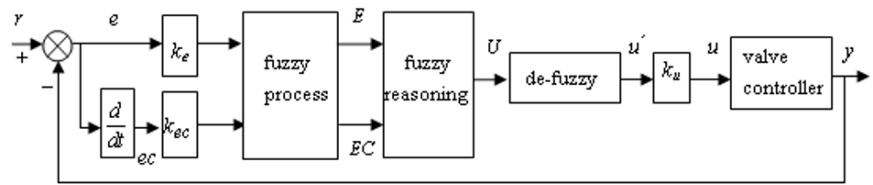


Fig.2. Structure of fuzzy controller

The error e and the error change rate ec are calculated firstly according to the given value r and the measured value y . Then e and ec multiply with k_e and k_{ec} and through fuzzy processing, the fuzzy quantity E and EC can be gotten. The value range of E and EC is $[-6, 6]$. The fuzzy subclass division of E and EC are { Negative-Big, Negative-Middle, Negative-Small, Zero, Positive-Small, Positive-Middle, Positive-Big}, i.e. { NB, NM, NS, 0, PS, PM, PB}. The fuzzy subclass division of U are { Zero, Positive-Small, Positive-Middle, Positive-Big}, i.e. { 0, PS, PM, PB}.

The value ranges of E , EC , and U are as follows:

$$E = (-6, -5, -4, -3, -2, -1, 0, +1, +2, +3, +4, +5, +6)$$

$$EC = (-6, -5, -4, -3, -2, -1, 0, +1, +2, +3, +4, +5, +6)$$

$$U = (0, +1, +2, +3, +4, +5, +6)$$

Based on membership function and experience of experts, the fuzzy reasoning rules are as [table 1](#).

Table 1. Fuzzy reasoning rules table

E	EC						
	NB	NM	NS	0	PS	PM	PB
NB	0	0	0	0	0	PS	PS
NM	0	0	0	0	0	PS	PM
NS	0	0	0	0	0	PS	PM
0	0	0	0	0	PS	PM	PB
PS	0	0	0	0	PS	PM	PB
PM	0	0	0	PS	PM	PB	PB
PB	0	0	PS	PM	PM	PB	PB

When E is Negative-Big and EC is also Negative-Big, it shows the soil water content is higher than normal and the soil water content will be increased continually. Therefore the measure that restrains the water content increase should be adopted. The control rule should be: If $E=NB$ and $EC=NB$ then $U=0$.

When E is Positive-Big and EC is also Positive-Big, it shows the soil water content is lower than normal and the soil water content will be decreased continually. Therefore the valve should be turned on to irrigate to the maximum.

The control rule should be: If $E=PB$ and $EC=PB$ then $U=PB$.

FIS editor of Matlab 7.0 was used to compute the fuzzy control matrix. After adjusting the output of fuzzy reasoning, the fuzzy control matrix can be obtained as [table 2](#).

Table 2. Fuzzy control matrix

E	EC												
	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
-6	0	0.5	0	0.4	0.4	0.2	0	0.2	0.4	0.4	2.5	2.5	2.5
-5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2.5	2.5	2.5
-4	0	0.5	0	0.4	0.4	0.2	0	0.2	0.4	0.4	2.5	4	4
-3	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	2.5	4	4
-2	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	2.5	4	4
-1	0.2	0.5	0.2	0.4	0.4	0.3	0.2	0.9	1.5	1.5	3.3	4.5	5
0	0	0.5	0	0.4	0.4	0.2	0	1.3	2.5	2.5	4	5	6
1	0.2	0.5	0.2	0.4	0.4	0.3	0.2	1.4	2.5	2.5	4	5	5.5
2	0.4	0.5	0.4	0.4	0.4	0.4	0.4	1.5	2.5	2.5	4	5	5
3	0	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	2.5	4	4
4	0	0.5	0	0.4	0.4	1.5	2.5	3.3	4	4	6	5.5	6
5	0.5	0.5	0.5	2.5	2.5	3.3	4	4	4	4	5.5	5.5	5.5
6	0	0.5	0	2.5	2.5	3.3	4	4	4	4	6	5.5	6

Table 2 shows that the larger e and larger ec lead to longer irrigation time. The result is reasonable. Central average value inverse-fuzzy-method is used to compute u' , then u' multiplies with k_u to get output u . Scale factors k_u is relative with the valve characteristic, soil types and other factors.

3. RESULTS AND DISCUSSION

The experiment was carried out in Langfang experimental farm (39.4N, 116.4E) of Soil and Fertilizer Institute, Chinese Academy of Agricultural Sciences in 2006. The selected cotton cultivar was mid matured cultivar Jimian25. Planting density was 52500 plants per hectare. Management measures were the same as normal high-yield management for the field cotton. Soil water sensors were installed in 20cm deep of cotton root in each plot.

In normal agronomic years, furrow irrigation is commonly set to be four times with relative small irrigation quantity during bud and square period, irrigation is usually set to be four to five times with mass irrigation quantity during flower and boll period, and irrigation is set to be three to four times with small irrigation quantity during cotton boll opening period. According

to the water-required rules of different cotton growth periods, the different irrigation strategy can be adopted automatically by the fuzzy control system. Irrigation time and quantity can be adjusted based on the environmental conditions. The lint yields of four plots under different irrigation manners are listed in [table 3](#).

Table 3. Cotton yield comparison of fuzzy control and on/off control irrigation

Number of plots	Lint yield(kg·ha ⁻¹)	Irrigation manner
1	1739.79	on/off control
2	1794.27	on/off control
3	1821.46	fuzzy control
4	1856.19	fuzzy control

The results indicate that the cotton yields are much higher in plots that adopt fuzzy control irrigation than in plots that adopt on/off control irrigation. Furthermore, the fuzzy control irrigation system uses less water quantity than the on/off control irrigation system. About 89m³·ha⁻¹ water is saved every time. The saving water quantity reaches 28% of total quantity in on/off irrigation manner.

4. CONCLUSION

The fuzzy control irrigation system studied in this paper combines fuzzy control model with automatic irrigation technique. The system has high control accuracy as well as rapid following response. Different irrigation strategy can be adopted automatically according to the water-required rules of different cotton growing periods. The results indicate that the control system can save water and improve cotton yield greatly. Therefore it has promising potential in precision farm applications. Further study is to integrate fertilizer-required rules of different growth periods into the control model, and then develop a precision irrigation and fertilization system ([Zhang Naiqian et al., 2002](#); [Liu Xiuzhen et al., 2006](#)).

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